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ABSTRACT

Ideas for chemistry laboratories, design curriculums, and instructional criteria are outlined for use in Asian secondary schools. Chemistry education and its changing aspects, teaching methods, planning and communication problems are discussed. Requirements for laboratory facilities are included with suggestions for laboratory furniture and equipment, space utilization, and services. Drawings, photographs, floor plans, and a reference list are given. (TG)

ED035215

STUDY

3

THE DESIGN OF CHEMISTRY LABORATORIES FOR ASIAN SECOND LEVEL SCHOOLS

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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ASIAN REGIONAL INSTITUTE FOR
SCHOOL BUILDING RESEARCH
Sponsored by Unesco
COLOMBO
1968

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ASIAN REGIONAL INSTITUTE FOR SCHOOL BUILDING RESEARCH

STUDY no. 3.

THE DESIGN OF CHEMISTRY LABORATORIES FOR ASIAN SECOND LEVEL SCHOOLS

by

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COLOMBO
1969

Frontispiece – Plate 1.

Adequate Space for Experimental Work

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The plates in this paper are from photographs by Max Hempel, Colombo.

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SUMMARY

The present project, relating to the critical assessment of the design of chemistry laboratories for Asian Second Level Schools, occurs at a time when the theory and practice of chemistry learning and teaching are undergoing changes of a somewhat deep-seated nature. In many countries of the region these changes are taking place fairly rapidly. The purpose of the paper is to suggest the evolution of a design for chemistry laboratories that will not only meet the changing emphasis in chemistry teaching but also facilitate the extension of this work and perhaps result in some improvement of quality in second level chemistry education.

The paper reviews the situation in relation to chemistry curriculum development and concludes that traditional laboratories are suited perhaps to the needs and attitudes of an earlier day.The objectives of educability in the context of developing abilities, skills and attitudes are clarified and the paper shows how, in the case of one country of the Region, the changes implicit in achieving these objectives in respect of chemistry learning and teaching are reflected in a second-level chemistry curriculum.

Clearly a basic change in curriculum and in teaching method and technique may require a change in the physical facilities provided for their implementation. The requirements of the pupil and the teacher are, it is postulated, the point of departure for all laboratory design thought.

The paper develops an approach to the design of laboratories for the changed situation and describes the thinking that has led to the construction of new prototype laboratory benches. These prototypes and the field trials to which they were subjected are described in detail. The preliminary conclusions drawn from the study are that the new benches can be provided at a quarter of the cost of traditional laboratory furniture; that it is possible to dispense with piped water and drainage in laboratory design and finally, that the polygonal shape has a decisive effect on the formation and working of small groups within the laboratory.

RESUME

Le projet actuel, se rapportant à une planification soigneuse de laboratoires de chimie pour les etablissements d'enseignement du deuxième degré en Asie arrive au moment que la théorie et la pratique de l'enseignement et la connaissance de la chimi subissent des changements considérables. Dans plusieurs pays de la région les changements ont lieu assez rapidement. L'intention de cette étude est de proposer l'évolution d'un plan pour les laboratoires de chimie qui répondra non seulement aux changements dans l'enseignement de la chimie, mais encore facilitera l'extensions de ce travail et, peut-être, résultera en une amelioration du niveau de l'enseignement de la chimie du deuxieme degré.

Cette étude expose la situation en rapport avec le développement du programme d'études de la chimie et conclut que des laboratoires traditionels ne servent qu'aux besoins et aux attitudes du passé. Les objectifs de l'éducation à l'égard des capabilités, des connaissances et des attitudes développantes sont clarifiés et cette étude présente comment, dans un pays de la région, les changements absolus, en accomplissant les objectifs à propos de l'enseignement et de l'apprentissage de la chimie, se reflètent dans le programme d'études de l'enseignement de la chimie du deuxième degré.

Evidemment, il existe la possibilité qu'un changement fondamental du programme d'études et de l'enseignement entraîne un changement des facilites a disposition pour l'exécution des travaux. Les besoins de l'étudiant et du professeur sont le point dé part pour toute planification d'un laboratoire.

Cette étude expose quelques propositions pour un plan de laboratoires servant à des conditions changeantes et explique les idées qui ont contribué à la construction d'un nouveau prototype de laboratoires et de tables d'expériences. Ces prototypes et les expérimentations auxquelles ils ont été soumises sont expliqués en détail. Les conclusions tirées de cette étude nous montrent qu'il est possible de construire des tables d'expériences dont le coût est réduit à un quart de celui de l'équipement traditionel de laboratoire. En même temps alle nous indique la possibilité de se dispenser de l'eau en tuyaux et du drainage et, finalement, on trouve que la forme polygonal a une influence décisive sur la formation et le travail de petits groupes dans le laboratoire.

PART I

EDUCATIONAL ASPECTS

1.0 Background Data and Comment

The teaching and learning of chemistry at the Second Level in General Education has a significantly long history in the Asian scene. In the countries classifiable in Groups B and C of "The Draft Model of Educational Development"1/ the traditions of chemistry teaching are not only of long duration but are both extensive and intensive. The experience in countries classifiable in Group A may be limited.

The present project, relating to the critical assessment of the design of chemistry laboratories for Asian Second Level schools, occurs at a time when the theory and practice of chemistry learning and teaching at this level are undergoing changes of a somewhat deep-seated nature, and in many of the countries of Asia itself the changes are taking place fairly rapidly. The purpose of the project itself is the evolution of an approach to the design of chemistry laboratories for lower second level schools in Asia that will not only meet the changed emphasis in relation to chemistry teaching at this level, but also facilitate the extension of chemistry teaching at this level, within the framework of resources available to the developing countries in the Region.

In this context, therefore, it is necessary to review the present trends and patterns of curriculum development in relation to chemistry teaching in particular, and science education in general. This will be attempted in outline in this part of the paper.

1.1 Chemistry Teaching - An Overview of the Position

Several factors have to be noted in relation to the pattern of Second Level chemistry teaching in the Asian scene today. One of these is the acute sense of urgency present in Asia, as well as in other regions, in regard to the extension and quality improvement in science education.

1/ UNESCO. An Asian model of educational development; perspectives for 1965-80. Paris, Unesco, 1966.

A second factor is the major trend observed in the Asian scene in relation to the enrolment pattern at the Second Level of general education.

A third major factor arises from the emergence of a theory and practice of curriculum design and development, particularly in the field of science education, and its active application in many countries of the Asian region. Some brief comment will be made in relation to each of these aspects.

During the last decade or two, chemistry teaching has been pursued at the Second Level in many Asian countries, essentially as a pre-requisite to later programmes of professional study in the fields of medicine, engineering and other such areas of activity. In the context of the rapidly increasing man-power requirements of the developing countries, the need for rapid extension of second level programmes in chemistry teaching has become a matter of major importance. In addition, the recognition by Asian nations of the fact that science is an integral element of modern culture, and that science learning in general, and chemistry learning in particular, should be an essential part of a general education of a citizen for "today" and "tomorrow", has made this sense of urgency even more acute. The general acceptance of this changed view point in relation to the objectives of teaching chemistry are referred to in a recent study relating to the curriculum of general education.2/

With manpower needs in mind, and also taking account of the enhanced awareness of the benefits that education can confer, enrolments at the Second Level have increased very markedly in many countries of the region. This is clearly seen by a study of the data in "A Draft Asian Model"1/. This trend is likely to be continued in the future. As a result, pupils with diverse abilities are participating in Second Level education and in the learning of chemistry at this stage. Hence the needs for changed practices, and provision of modified facilities has become acute.

2/UNESCO. Meeting of Experts on Curriculum of General Education. Final report. Paris, Unesco, 1968.

While earlier, when the number of pupils participating were relatively small, and when from within this number a significantly large percentage did in fact pursue programmes of higher education, a pattern of chemistry teaching and learning, and the physical plant used for the purpose, could be of a particular type. For the new pupil population, with a wide spectrum of abilities, the objectives and patterns of teaching need considerable revision. So too do the facilities and resources necessary for learning.

In addition, during the last decade, there has emerged a coherent body of theory and practice of curriculum design and curriculum evaluation. These conceptual insights have found fruitful application in the fields of science and mathematics education at the Second Level. This activity has had a major impact in the field of chemistry education at the Second Level, and in the Asian scene, too. The development programme has been gathering momentum, especially with the initiation and expansion of the UNESCO Project for the Improvement of Chemistry Teaching in Asia.

In the traditional pattern of chemistry learning widely prevelant in many countries of the Region, chemistry has oftimes been treated largely as a vast body of factual knowledge to be learnt assiduously and rapidly. The pressure for rapid learning, and the assimilation of a body of facts has fallen more markedly on chemistry than on physics. The result of this tendency is to push to lower and lower stages, studies which formerly were presented at higher levels. Pupils usually emerge with a large number of items of information, and there is a tendency to pass over this material too hurriedly for its origins to have been appreciated or its nature understood. On account of this, even the very objectives of preparing students for later programmes of professional study are sometimes defeated.

In this outmoded approach to learning, the laboratories and the equipment in them have been looked upon as aids to the teaching of facts. In general, under the best conditions, the laboratory has been used as a venue where enunciated theories, or stated facts are verified by the teacher in the company of the pupils, or are illustrated qualitatively to provide some minimal meaning to terms and phrases stated in theory. In addition to this activity, students are also invited to carry out simple analyses qualitatively and quantitatively, only weakly linked with the theoretical conceptual material given in the classroom. Under average conditions the chemistry lesson in the framework of traditional patterns of chemistry learning tends to be an esoteric and somewhat "glorified" cookery session, at which preparations and analyses are carried out relatively routinely and with little meaning. The traditional laboratories have been evolved essentially to meet and serve these needs.

It is important to note that the major traditions affecting large groups of teachers in the Asian Region are characterised by the description indicated above.

Nevertheless, it is important to recognise that while the above general statements are in the main true, outstanding teachers have always worked and guided pupils, and in so doing have exploited inflexible and rigid laboratory facilities with considerable versatility. But these instances are few and far between.

1.2 Changing Aspects of Chemical Education and Problems of Change

The pattern of change in chemical education at the Second Level occuring today, is perhaps best illustrated and described in the recent classic Report of the Education Commission 1964/66, Government of India, Ministry of Education, 1967. 3/

The Report, in the section dealing with science education, highlights the change from traditional "technologies" to a science based technology and suggests that this change must be further stimulated through the improvement of science education in schools. Problem solving and analytical skills must be developed and a spirit of enquiry promoted. This last point, the Report points out, is important, not only in respect of the attitudes it creates towards science education but also because a true spirit of enquiry helps loosen the bonds of dogmatism and consequently to reduce idealogical tensions.

3/ INDIA. Education Commission, 1964-66. Report; education and national development. Delhi, 1966.

The changed emphasis in relation to science education described in the Report is applicable without reservation in the field of chemistry learning at this level. In addition to the above, a new emphasis in relation to learning and a further and more significant objective has also emerged, which has special relevance to science education.

This is well described in the Final Report of the Meeting of Experts of Curriculum of General Education held in Moscow in January, 1968, under the auspices of UNESCO 2/. The Report emphasises the rapid obsolescence of knowledge and the need for continuing education. Self education, after the period of formal schooling involves the development of educability or the concept of "learning to learn". This development must take place during the period of the child's formal education and requires delineation in the context of curricular operations and integration in the different curricular areas.

The changes implicit in the above in relation to the objectives of chemistry learning and teaching at the Second Level are today reflected in the curricula which are being designed in many parts of Asia, especially under the impetus given to chemistry teaching by the UNESCO Project.

A particular example of such a change, attempted in 1962 and now being implemented on a national scale, is found in Ceylon. A unit from the Syllabuses of Instruction of the Ministry of Education, Ceylon, (given in appendix I) is illustrative of the changed pattern of teaching.

The changed emphases in objectives are also reflected in the examination syllabuses in many Asian countries. One such example is the G.C.E., O.L. Chemistry Examination Syllabus and Prototype Question Paper of the Ministry of Education, Ceylon. (appendix II)

The changes which are envisaged in these statements of educational and executive design, are relatively ambitious, and demand a significant change of attitude on the part of the teachers. They also demand that the teachers should study this subject with these newer view points in mind, firstly, for their own understanding to be enhanced, and secondly, to develop the competancies to seek the wider objectives. To say the least, this is a very difficult problem of reorientation and in-service training, and therefore, needs to be supported in every way possible. Physical facilities such as laboratories, furniture and equipment designed to assist in the execution of the modified programme are important. The present project, therefore, suggests that the creation of an environment which is not only functionally valid, but which actively stimulates a day to day inquiry and self-learning approach is a very critical aspect of design in the context of the newer curricula.

The problems of educational development are clearly brought out in very general terms in a recent study entitled "The World Educational Crisis - A Systems Analysis" - Philip H. Coombs IIEP UNESCO 1968.[4]

"The main difficulties are lack of resources and inertia due to lack of adaptability of present educational systems. Traditional preferences for certain types of employment prevent nations from developing the kinds of education they most need for economic growth. Paradoxically education as the prime purveyor of knowledge, has failed to apply to itself the function it performs in society at large."

1.3 The Impact of the Changes on the Use and Design of Laboratories

The enhanced awareness of the value of Science Education and the contingent increase in enrolments in science courses necessitates, on the part of the National Governments, heavy capital committments in relation to the extension of science teaching facilities in general and chemistry teaching facilities in particular. Accepting the validity of the demand for additional chemistry teaching and learning facilities, it becomes vitally important to evolve designs which minimize the initial expenditure. Even small reductions have significant impact, because at this level in general education, the development programmes are significantly large, and the total capital costs are high. In the context of limited resources in developing countries this is critical to educational development. The evolution of furniture and storage facilities so that they become more economical and yet functionally valid is one aspect of design which needs to be very carefully examined and considered.

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[4] COOMBS, P.H. The world educational crisis - a systems analysis. Paris, I.I.E.P. /Unesco, 1968.

As has been remarked above, the enhanced participation in chemistry learning bringswith it a wide spectrum of abilities and attitudes into the classroom. On account of this and on account of the fact that modern chemistry is becoming increasingly abstract in may ways, the teaching aids that are essential for presenting abstract concepts to the average pupil become more costly and varied. The experimental support that needs to be given with the changed pupil populations is much more than would have been the case if only selected pupils pursued programmes of studies. The additional equipment needed demands not only additional capital expenditure but also additonal storage facilities.

Another facet which is important in the changed situation is that, with a wide spectrum of abilities in the classroom, the time available for teaching becomes a severe limitation. Except in very large schools "ability setting" is not feasible and even in such situations whether it is desirable or not is a question that needs to be considered. The limitation of time makes it necessary for equipment to be readily available to the teacher and readily disposed of after teaching. If individual and group work is considered important, then the problem of organising the work-places and storage facilities becomes a major problem of discriminate design. In fact, if any one factor can be isolated as placing severe limits on the targets of achievement of science learning, it is certainly the availability of time in relation to the curriculum. Unlike financial resources and even unlike trained staff, time is the element which is very difficult to extend.

In addition to the above factors, if we accept the major direction of change in modern chemistry teaching, namely, fostering of the attitude of inquiry and the development of a skill in learning to learn, then the problems of organising the physical resources to meet objectives, becomes particularly important. In the main, nurturing attitudes of inquiry on the part of pupils demands that the pupils work in small groups at relatively "open-ended" experiments.

This entails, in addition to a wide variety of resources readily available, a physical environment which promotes small group work in a coherent manner. Furthermore, if the physical environment can be designed so that the teacher can also, without much difficulty, make himself "disappear" as the person who knows, and merge with the groups in seeking answers to problems, then the broader objectives are likely to be achieved more effectively.

Ideally this would best be achieved by having work places for each individual student, and arranging for such teaching supervision as is necessary. In practice, initial capital costs, recurrent costs as well as teacher-pupil ratios, such as are common in developing countries, make it imperative to have small groups at work rather than individuals. 5/ The particular group strengths can vary, but, depending on the capital costs involved, groups of up to 6 may need to work together. The question of design then resolves itself to that of providing work stations for such groups. The physical geometry of the work station should itself be such as will encourage small group activity.

At the same time there is a significant and valuable place for teacher demonstration, and group, and whole class, discussion. The design of work stations needs to be planned so as to meet these various criteria. It will be recognised that meeting one criterion ideally, often militates against another. The design problem hence becomes one of achievement of appropriate compromises within the frame-work of available resources. A tentative arrangement which could meet the needs in the Asian context is outlined in this study. It is important to recognise however, that the rationale of thinking is more significant than the ultimate details of the design shewn. The case study thus indicates little more than a pattern of analysis which could lead to good design.

It will be accepted that whatever method of teaching is adopted, flexibility and safety are major elements of good design. An attempt has been made to achieve these simultaneously with the other objectives indicated.

5/ ALLES, JINAPALA. Financing and costs of first and second level education in Ceylon, 1952-1964 /by/ Jinapala Alles, S. Victor de Silva /and/ Francis W. W. Kulatunga. /Colombo/ 1964. Issued by Division of Secondary Education, Ministry of Education, Ceylon.

In a chemistry laboratory at lower second level, it is usually assumed that a multitude of facilities such as water and gas are absolutely essential. In Asia, the rural environment in which many secondary schools are located, does not permit such facilities to be established readily. This has therefore also entailed a study of the extent to which these facilities are critical to the conduct of the programme of study. It is postulated that education systems can, provided detailed analyses are available of their syllabuses of instruction, make appropriate compromise decisions as to the need for such specialised facilities. In the present case study, for the programme of work as has been evolved for use in Ceylon, field trials suggest that, with an appropriate design, it is possible to dispense with facilities such as running water and gas without seriously affecting performance. This assertion is not to be understood to imply that these facilities are not desirable when they are easily obtainable and can be afforded.

It is worthwhile noting that a meaningful design such as the one considered here can be evolved only after outline syllabuses have been consistently and comprehensively expanded to syllabuses of instruction, and a detailed specification given of the demand which will be made on the laboratory for the entire course.

Throughout the design, the major working assumption is that a laboratory is a place where conditions can be systematically and selectively controlled and observations made. It may well be worthwhile to ignore the stereotype laboratory and think about the problem afresh and from a basic, and functional standpoint. For example, the equipment in a laboratory itself can be classified functionally, namely,

1.00 Material substances (Materials)
2.00 Apparatus - Complementary
    2.10 Tools
    2.20 Auxiliary Aids
3.00 Apparatus - Principal
    3.10 Observational Aids
    3.20 Control Aids
4.00 Teaching Aids

3.00, Observational and Control Aids, may be viewed as especially significant in a science laboratory. 2.00, Tools and Auxiliary Aids, may be considered lower down in the hierachy. (In a workshop the reverse may be more appropriate). Materials are basic and Teaching Aids may be any one of 1.00, 2.00, 3.00 or any combination of these.

From the viewpoint of laboratory design provision must be made for storage of the items classified under these heads. The more important items should be readily available at or near the work station whilst those items less frequently used may be kept conveniently but perhaps in a separate space or "store".

It is significant, that at no stage has it been postulated that the mere presence of these classes of items makes a location a science laboratory. Mere observation and data gathering, however, elaborate, is not a science. But a science laboratory will contain the above items.

It will be noticed that on this basis, an agricultural research worker's observational plot (e.g. part of an experiment on plant growth) will become a laboratory when he observes, records, and reflects on it. This may be out in the field; and there will be no roof over this laboratory. The operation will be an experiment in the full sense of the word, for he will be observing the growth of plants, systematically, under controlled conditions (whatever the particular conditions be). Some other workers may, in this sense, have laboratories which are even more unconventional. This is not only a valid extension of the concept of a laboratory but a very necessary one. Science teachers and their pupils have considered faucets, sinks, glass tubes, rubber tubes, intricate glassware, etc. as absolutely essential in a laboratory. Their use and importance in certain laboratories is not contested, but their necessity in every laboratory is. Often the "scientist" has been considered simply the man in this labyrinth of equipment. This is perhaps too limited a conception of the situation. It is this restricted view of a laboratory and a scientist that this broadened viewpoint of a science laboratory seeks to modify. The restriction of the term "laboratory" to a location with highly specialized materials, highly refined observational and control aids etc. is justified only by common usage. From the point of view of the practicing scientist the whole world is a laboratory and everything in it is equipment and materials for the practice of science. This wider understanding may be valuable to the science teacher as well. With the extension of science as a part of general education, it will become an essential point of view.

Hence in considering this study, the organization of a laboratory should be looked upon as an adaptation of a limited part of the total chemistry learning environment.

PART II

CHEMISTRY LABORATORY DESIGN

2.1 General

The rationale for this study has been well defined by Middleton 6/ who postulates that:-

i) No problem is so familiar, its traditional solutions so proven, that it can escape re-assessment from every view point;
ii) the changing requirements (of the student and teacher) constitute the point of departure for all design thought;
iii) every problem is to be solved as elegantly as possible using minimum means for the precise end in view;
iv) all design thinking is informed by the concept of continuous space.

Part I of the study suggests that chemical education will depend for its success on arousing the curiosity and capturing the interest of the student. "Interest means that the learner identifies himself with the kind of activity which his environment invites". 7/ Although environment in this context refers to the structure and content of the curriculum and to the method of instruction, it may also, in a somewhat less philosophical sense, refer to the built environment; that is to say to the physical surroundings in which the educative process takes place.

What are likely to be the main requirements of an inviting built environment?

6/ MIDDLETON, M. Group practice in design. London, Architectural Press, 1968.

7/ BRUBACHER, J.S. Modern philosophies of education. Tokyo, McGraw-Hill, 1962.

The first, and perhaps the most easy to satisfy, is that of comfort. Furniture should bear some relationship to the body sizes of the children using it; there should be adequate illumination on the working surfaces; there should be no noise* and finally, the space should be thermally comfortable.

The second requirement of the environment is that it should be permissive in relation to the curriculum and to the teaching method. Specifically it should encourage through the way in which it is designed:

i) control of the learning situation by the teacher;
ii) the possibility of the teacher adopting the role of co-worker with the students;
iii) more informal evaluation by the teacher of the children;
iv) an ability on the part of the individual child to work with and learn from peers;
v) an ability to work indepently with good work habits. 2/

The designer must appreciate that the laboratory will be the scene of many changes in teaching method. Initially, the teacher may be expected to compromise between the methods formerly employed in teaching chemistry and the methods demanded by the new ideas. Such changes as take place will be made slowly as experience and confidence are gained.

The architect's response to this situation may be the provision of both group and individual work benches which are designed in such a way as to permit of experiments the precise nature of which often cannot be predetermined.

Within this setting it must be possible for the average teacher to foster a critical approach to chemistry, emphasising experimentation and enquiry rather than mere factual assimilation. The laboratory will inevitably reflect in its design the very loosely structured teaching situations which will result from a heterogeneous group of children "learning to learn" about chemistry.

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* Noise may be defined as undesired sound.

The traditional laboratory probably only meets one of the requirements outlined above - that of encouraging an ability to work independently with good work habits.

The long, wide benches are certainly not conducive to the grouping of children around a problem. Moreover, the teacher's demonstration bench, commonly raised on a dais at one end of the space, neither encourages the idea of experimentation and enquiry by the child nor does it foster the concept of the teacher as a co-worker. The traditional laboratory represents in fact a very satisfactory design response to a teacher-centric situation in which the children, formally arranged in rows, are required to observe an experiment and then repeat it themselves either individually or in pairs at their own work stations.

The following has been quoted in this context:

> "The oldest and youngest
> are at work with the strongest
> The cattle are grazing
> Their heads never raising;
> They are forty, feeding as one! "

Written in March - Wordsworth 1802

and it is this situation so common in Asian science laboratories, that is in need of reassessment in the light of current chemistry teaching methods.

2.2 The Regional Situation

Within the framework outlined above, the nature of the environment provided for lower second-level chemical education must also be related to the pattern of development of education in the region which in turn is influenced by the educational economy. At country level there will be even more specific parameters for chemistry laboratory design.

In most States of the Region* there is a serious shortage of secondary school places, and the rate at which new places can be provided depends not only on such factors as the production of trained teachers, but also on the skill of architects and engineers in designing buildings which meet the educational requirements at the lowest possible per place cost. The lower the per place cost, the greater the number of places that can be provided. Minimum means must, therefore, be employed for the precise ends in view.

These considerations, coupled with the changing concepts of chemical education, require perhaps, a rather more radical approach to laboratory design than might be thought necessary in more affluent parts of the world. This is, from many points of view, a great advantage as it encourages a very careful examination of the fundaments of laboratory design and raises some very basic questions such as,

> how much water is required per student place? Does it need to be piped? Do we need a drainage system? Is electricity and gas needed and how often? Should the student sit or stand at work? What of chalkboard locations in a pupil-centric teaching situation? What equipment should be to hand in a loosely structured teaching situation? What is the best size for teaching groups? Is a teacher's demonstration table needed? Where should it be located?

Many of these questions are stimulated not only by the desire to provide a suitable environment, but also by the importance of providing this environment as cheaply as is compatible with the teaching and learning needs. The answers are, in the Asian context, of some importance as new methods of chemical education are rapidly being introduced in the Region. Ceylon, India, China, and the Philippines are but a few of the Asian countries in which developments in chemistry learning are taking place and

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*Unesco's Asian Region comprises

Afghanistan
Burma
Cambodia
Ceylon
China
India
Indonesia
Iran
Japan
Korea
Laos
Malaysia
Mongolia
Nepal
Pakistan
Philippines
Singapore
Thailand
Viet-nam

it is essential that the progress made with curricula and chemistry teacher training be matched by the provision of new laboratories designed to cater for the changing curricula and methods.

Some progress has, of course, already been made with this work, notably in India where the National Council for Educational Research and Training has assisted in the publication of designs for laboratories attuned to the Indian Chemistry Curriculum and the associated teaching methods. 8/

The purpose of this Study is not, however, to suggest a final solution to the problem of laboratory design for the emerging chemistry. Rather it attempts to indicate the way in which the design problem can be approached in relation to a particular educational situation - that of teaching the new chemistry schemes in Ceylon. The method of approach which can be applied in any country, is essentially one of definition of the problem, study, field trials of the solution and evaluation of the results. The study is, in every sense open-ended. There is, as will be seen in the pages that follow, room for continuing development, patterned on the changing situation in chemistry teaching. More extensive field trials, and further evaluation will inevitably suggest more modifications to the laboratory arrangements proposed and there will be a continuing need to match the cycles of development in curriculum and teaching methods as they occur.

The form of chemistry teaching in Ceylon requires some explanation if the design solution arrived at is to be understood and the relevance of this study to other similar situations in the Region made clear. In the early 1960's schemes of work were produced for chemistry teaching in Ceylon in which the total material to be studied is broken down into units (part of one of which is given in Appendix I). Each unit is in turn arranged logically in the form of a series of experiments and discussions. Individual experiments are arranged in such a way that teaching procedures, content and activities are suggested and the main teaching outcomes

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8/ INDIA. Committee on Plan Projects. Report on science education in secondary schools. Delhi, 1964. (COPP/SS/3/1964) are outlined. Significant comments are provided on the experiment itself and also on connected experiments or other material which may help the teacher. The essential character of the schemes is suggestive rather than strictly didactic. Emphasis is placed on practical work in groups and the class may be organised so that different groups carry out different experiments at the same time. Under no circumstances, it is emphasised, should demonstrations or mere descriptions replace work that could be carried out by the children themselves.

As far as equipment is concerned, the schemes draw attention to the need to improvise. Faraday it is pointed out, used a few bobbins of wire and a nail in his experiments, not the polished equipment that bears his name whilst Oersted never employed the apparatus named after him. Much traditional equipment from the supply houses is replaced in the new chemistry by simple apparatus whilst larger apparatus such as tube furnaces, retorts and Woulffe's bottles are no longer needed as their main function - that of obtaining reaction products in sufficient quantity for demonstration - is no longer relevant.

Most of the experiments in the schemes are at "test-tube" scale. This saves material, minimises hazards and reduces requirements for storage space.

2.3 The Design of Benches

In the context of this approach to chemistry learning, the point of departure for the present study was the laboratory learning group, the group in which the students work with and learn from peers.

There is little evidence in the considerable published research on Group Structure to suggest that a teaching group of one size is likely to be more effective than that of another. It would seem the three member group may present a problem in respect of group dynamics and can best be avoided. Similarly in a two member group one of the members may solve the problem and transmit his answers to the other member. It has been shown 10 / 11 / that children working in pairs were more resourceful and accurate than when they worked as individuals possibly due to the need to communicate about their work to other children.

It is clear, however, that the larger the group, the greater the knowledge available to it from its members each of whom add to its problem solving capacity. Very large groups pose a control function problem.

In the present study groups of 5 or 6 children were selected (Figure 1) as the basis for the design of furniture, thus avoiding the problems associated with very large and very small groups and also relating the groups to the availability of equipment in Ceylon schools.

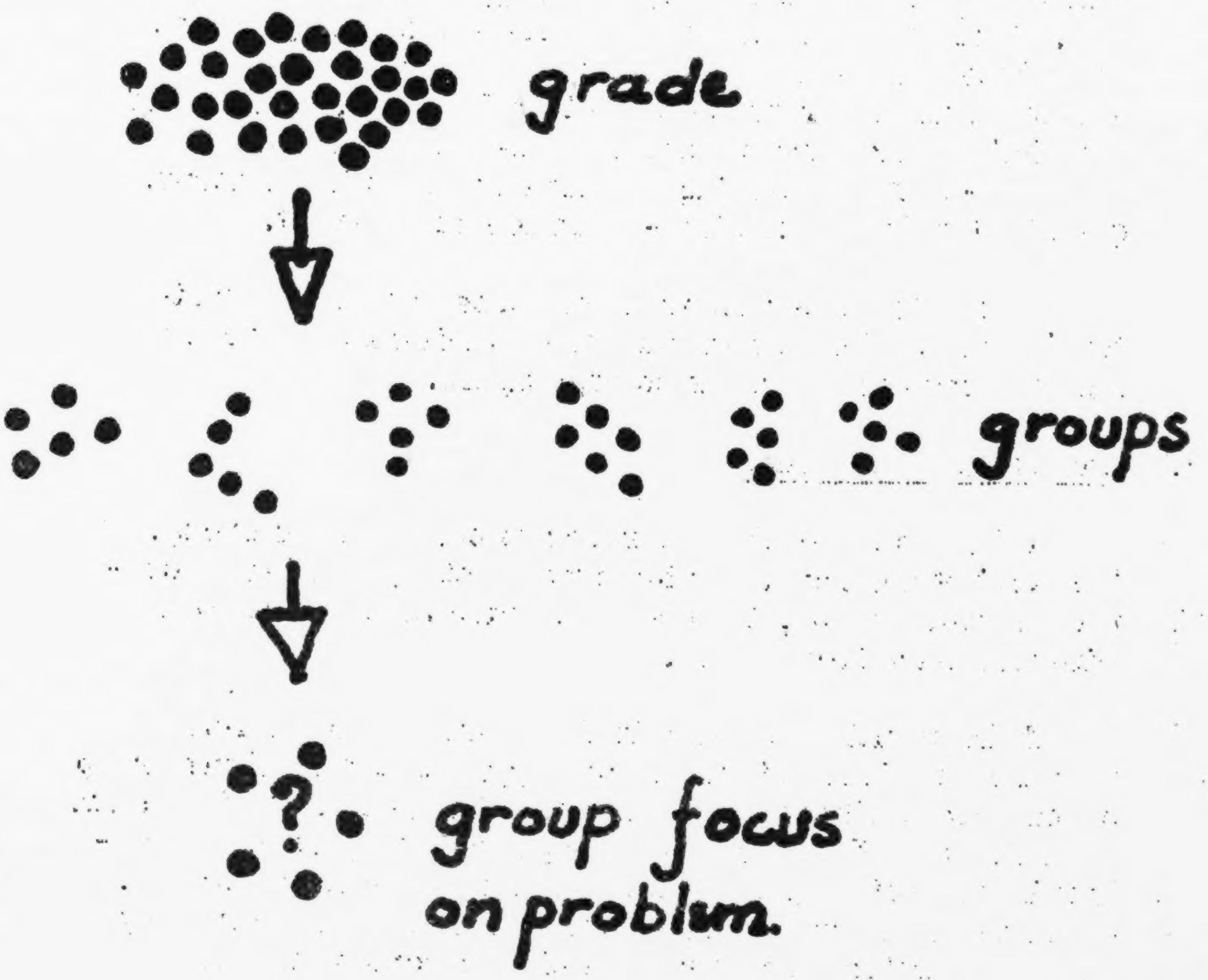


Figure 1 - The Laboratory Learning Group

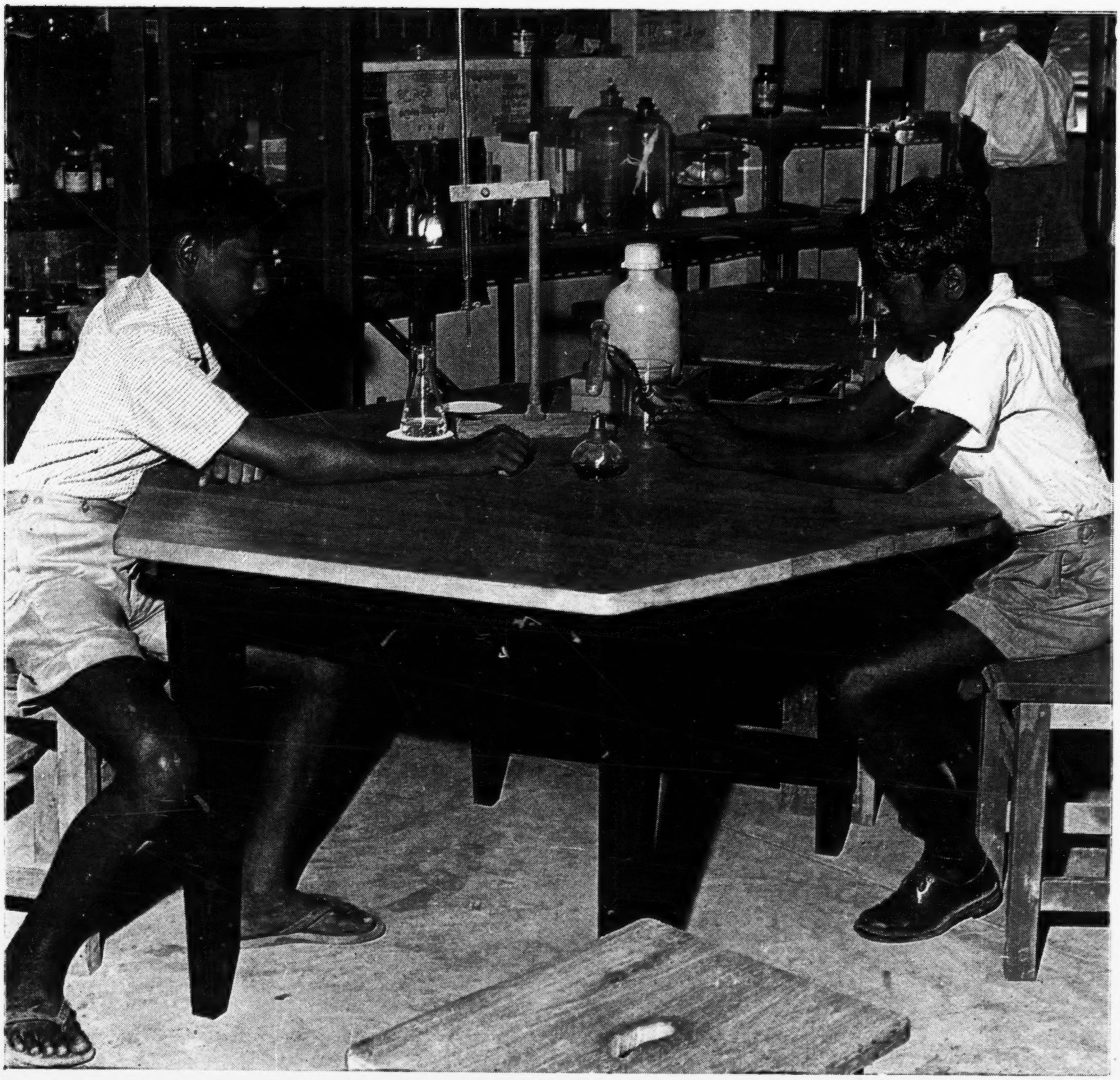


Plate 2.

Bench top sized for comfortable reach to centre.

The form of the resulting work station for a group of five children then proceeded from a study of space needs in relation to body sizes and of the likely maximum area required for the experiments suggested in the schemes of work.

In Ceylon, children studying 'O' level (Junior High School) chemistry, are usually aged 14 and 15, the subject being taken in the last two years of secondary education and before commencing higher secondary education. 12/ Using anthropometric data for 14 year old Asian children, a minimum work bench was designed, as shown in Figure 2, the plan dimension of which was based on the comfortable reach of a 14 year old. (Plate 2). At this bench five children can sit or stand and write or experiment comfortably. The bench provides, moreover, space for the largest experiment in the schemes of work - probably that involving study of the action of concentrated sulphuric acid on ethyl alcohol. 9/ As has been mentioned above most of the experiments will be with simple apparatus and often using equipment similar to that of the original researchers. "Test Tube" scale investigations are recommended and thus the area of bench required for experiments will be significantly less than that needed for more traditional teaching. Adequate space is also available for note taking but the benches are not large enough to act as a repository for the piles of books that many children commonly carry from class to class. For this a separate book and bag storage rack is suggested below.

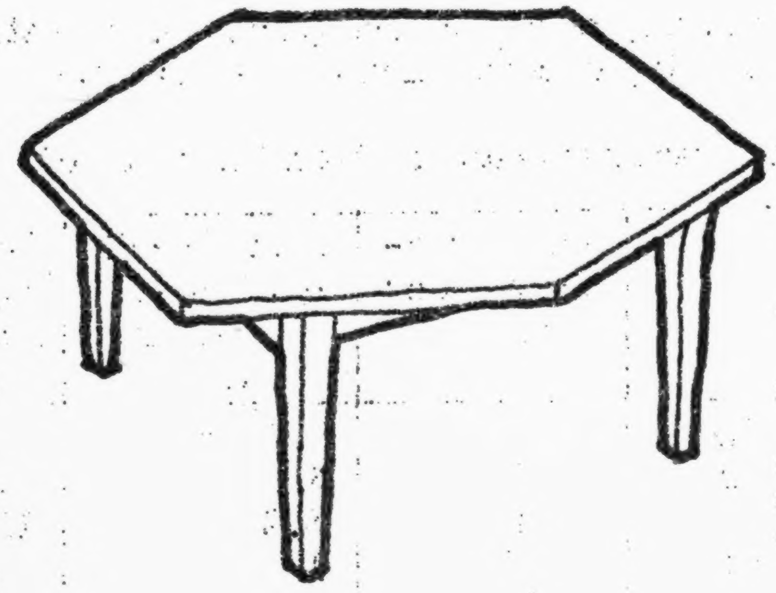


Figure 2 - Minimum Work Bench

2.4 Services

Having decided on the size of table for group experimental work, the next consideration is that of services and equipment storage. The questions posed in this connection were:

a) How best can water, heat and electricity be provided?
b) What equipment is needed at the bench (as opposed to the store)?

There can be little doubt that piped water, main drainage, gas for heating and mains power represent the services in their most convenient and most usual form. But in the Asian context where in many countries and for years to come, up to 80% of the population will be studying in rural areas, frequently without piped water, often without power and very rarely indeed with gas, the ideal solution is frequently impossible. Moreover main services may comprise from 48 to 20% of the total cost of the laboratory*and, in countries without steel, involve expenditure of precious foreign exchange.

It is necessary, therefore, to consider the need for services from a very fundamental view point and to arrive at a low cost solution which not only fully meets the teaching needs but bears relevance to the situation as it is.

A detailed study of the Ceylon Syllabuses of Instruction shews the following in connection with services:-

i) Water - requirements per teaching group of 5 children

Year	Term	No. of occasions water used	Total Quantity of water needed**in one term	Total allowing for 100% margin of error
1st	2nd	36	3.6 litres	7.2 litres
1st	3rd	21	3.2 "	6.4 "
2nd	4th	19	8.2 "	16.4 "
2nd	5th	6	1.9 "	3.8 "
2nd	6th	18	2.9 "	5.8

---

* Based on detailed cost studies of schools in the Region made by ARISBR in 1967-68.

**The quantity needed for the actual experiment plus the estimated need for washing.

The maximum use in any one term is that of the 2nd year, 4th term and the quantity 16.4 litres. If this is provided in a 3 litre aspirator at group bench then the aspirator will require filling (from some convenient, nearby well or other source) about 6 times in any term for each grade. Of course if several grades are using one laboratory then the number of times the aspirator will be filled will be the sum of the total water requirements divided by the aspirator capacity.

ii) Drainage of waste water - As the quantity of liquid waste is unlikely to exceed 16.4 litres in the "worst" term of the year course, it can be disposed of by hand. It was decided to use small plastic sinks to meet this situation (slightly cheaper than ceramic sinks and less likely to cause breakage of glassware dropped in them). At the end of each teaching period the sink and contents could be carried outside the laboratory and emptied by hand in a convenient place.

iii) Heat - The Schemes of instruction indicated that heat is required mainly for heating test tubes and occasionally for heating 100 and 150 ml beakers. The Ceylon Equipment Lists in fact provide spirit lamps and primus stoves for this purpose. There is thus no need for gas services either from a main supply or from an expensive petrol-air generator plant near the laboratory.

iv) Power - The major requirement for electricity occurs in experiments in electrolysis and can be met by the provision of from 3 to 6 Nickel-iron batteries. These are included in the Ceylon Standard list of equipment.

The second question is that of the equipment needed for day to day use and requiring storage near the bench. Major and infrequently used items of equipment would of course be kept in a separate, locked store. It is an obvious convenience on the other hand, to have commonly used items such as test tubes, beakers and the like, at the work station.

A small rack was, therefore, designed to house the following commonly used aids:-

1 dozen test tubes
2 test tube holders
1 heater (spirit lamp)
2 tripods
2 wire gauzes
1 thermometer
2 stirring rods
2 x 400cc. beakers
2 x 250cc. beakers

2.5 The Combined Bench Unit

The most preferred arrangement of benches, sink and storage unit was found to be that shewn in Figure 3. In this, two benches each with five work stations, are linked together by a sink and a common storage unit. Aspirators are arranged at each bench with taps overhanging the sink. The linking unit is a loose wooden slatted shelf hooked loosely over rails at each bench. The shelf which is not fixed, can easily be removed and the benches separated for use as six-sided tables.

Prototypes of the benches were built in the Institute and three adjustments made to the positions of legs, storage unit and linking rails before finally sufficient modified units were made and a field trial commenced at a secondary school in a rural area near Colombo.

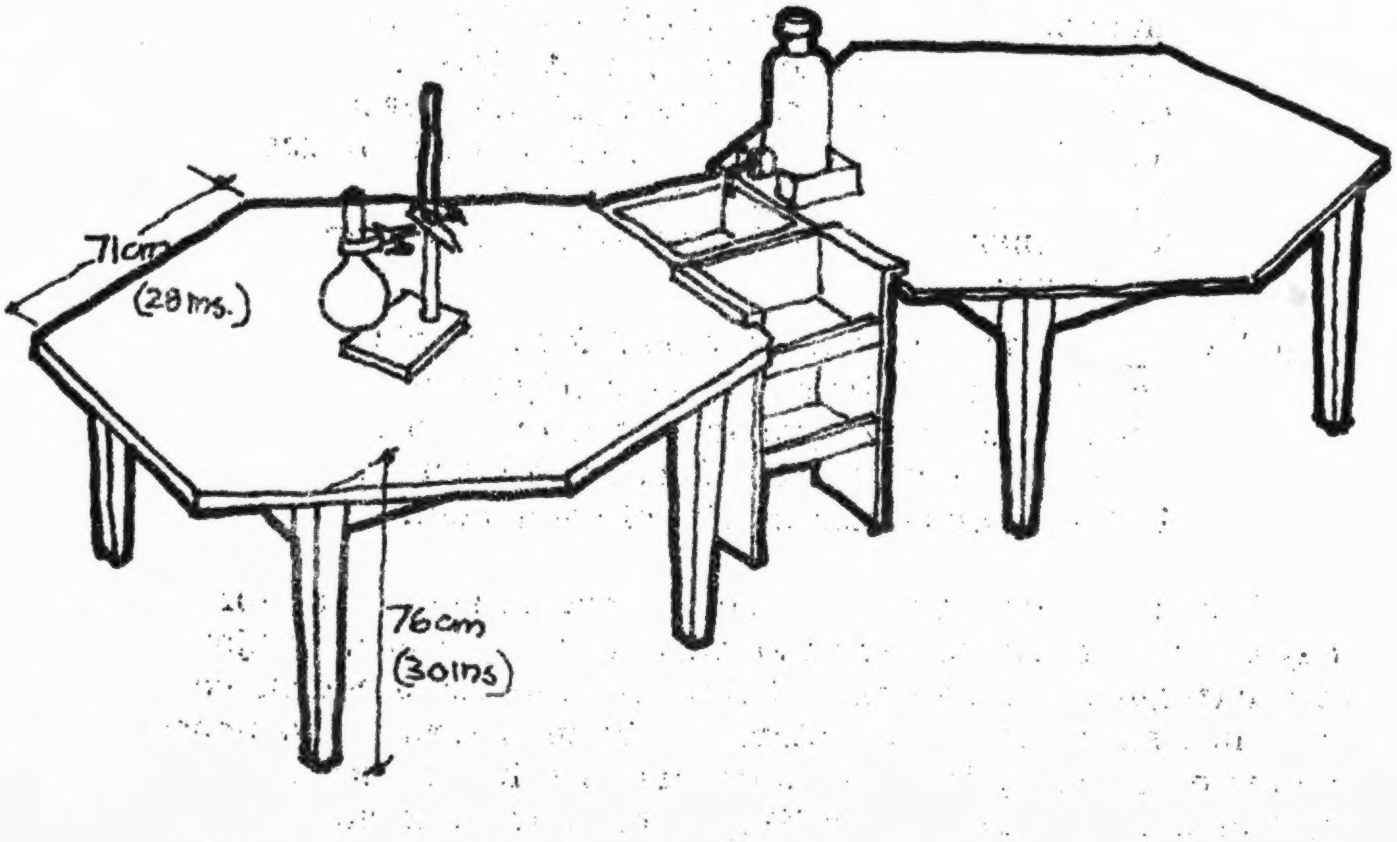


Figure 3 - Prototype Bench Unit for Two Learning Groups

Before describing the results of the field trial it is useful to summarise the approach adopted in arriving at the field prototype. A similar approach would be valid in any country of the Asian region but might, depending on the circumstances, yield quite different results.

The approach involved:-

Stimulation of an enquiring attitude

Method	- individual experiment and lecture demonstration part guided by teacher
Situation	- individual enquiry undesirable and impracticable due to cost Work in groups Group size depends on group psychology and availability of equipment (groups of 5 in Ceylon)
Group working on topic	- focus on one area of bench (the experiment) - arm length is radius of group - circle of polygon obvious shape of bench in relation to arm radii of 5 students
Guidance by teacher	- ready access to each group focus of attention of group moveable from bench to chalk board or demonstration bench
Time vital	- lessons brief therefore basic equipment needed at bench, not store.

2.6 The Field Trial

The trial was conducted in an unfurnished laboratory space in a standard secondary school. Two sinks formed the only fixtures and as the water supply system was not yet operative the trial was able to proceed as if in a situation where water was available only at the nearest well.

Although the trial was primarily of the laboratory bench, it was necessary to provide some storage and other supporting facilities and these were developed as the trial proceeded. The developments themselves are of interest as they emerged from the teaching, as opposed to the learning needs. They are, therefore, described later in this paper.

The furnished laboratory is shewn in Figure 4. The location of the benches was initially decided by the illumination levels but as will be described below, the benches were moved around as the teacher familiarised himself with their possibilities. Indeed, one of the results of the trial was to demonstrate the complete flexibility of the furniture, providing a sharp contrast to the rigidity imposed by traditional heavy, fixed benches.

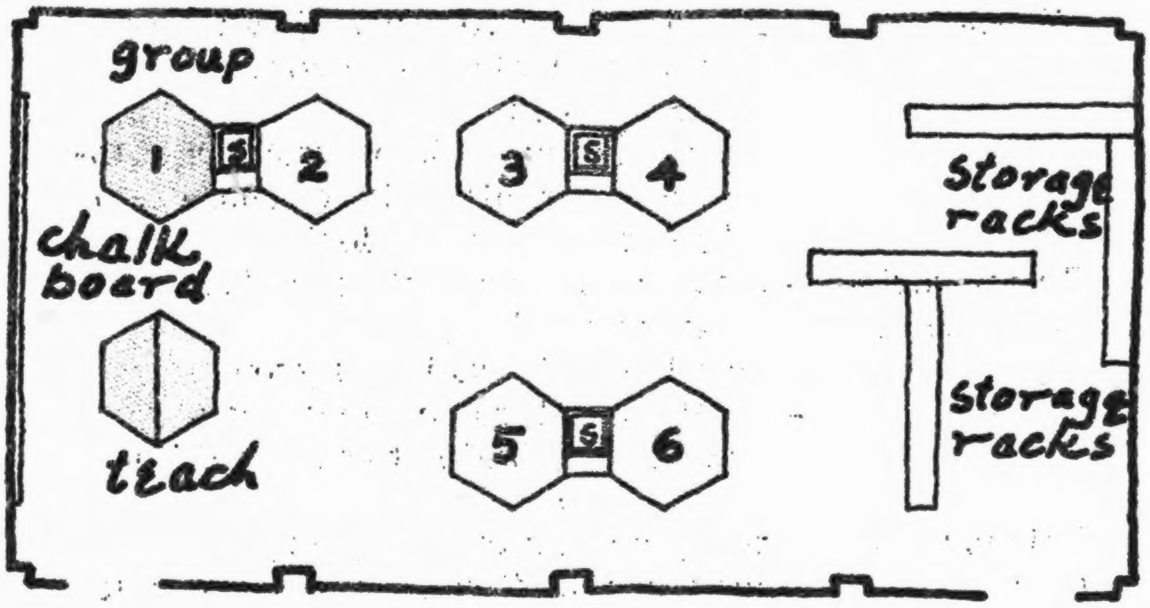


Figure 4 - The Trial Laboratory with Original Furniture arrangement.

The study of the laboratory in use was undertaken by one of the authors assisted by a Senior Science Inspector from the Ceylon Ministry of Education and Cultural Affairs. However, many other specialists in both Science teaching and building design visited the trial during the period for which it was in progress and opportunity was taken to record their comments and, where appropriate, to adjust the furniture.

Furniture adjustments have continued throughout the trial, the Institute's carpenter re-modelling the benches as experience was gained and as minor alterations were suggested.

The study of the benches in action was not however undertaken in an ad hoc manner. Before the trial was commenced a programme was prepared and all visits have resulted in observations being made systematically against the items given below:-

FORM OF REPORT FOR VISIT TO FIELD TRIAL OF CHEMISTRY FURNITURE

General:

The initial assumptions made were as follows:-

a) Concerning teaching method - that the shape of the bench will favourably influence the grouping of students, permit effective demonstration at a bench by the teacher and reduce the movement of students through provision of basic glassware and equipment at the bench instead of in the store.
b) Concerning the design of the bench - that it should be correctly dimensioned having regard to the body sizes of the students and to the activities to be undertaken on the bench top; that the bench should be stable. (The materials of which it is made are not be considered as they will vary from country to country of the region).
c) Concerning water services - that one, 3-litre aspirator and tap, filled at intervals, will provide an adequate supply of water and that a portable sink, emptied as the occasion demands, will provide an adequate means of liquid waste disposal.

Observations:

a) Comment on effect of bench on student group formation for experiments. Does each hexagonal bench result in the formation of one group?
b) Is the size of bench top adequate having regard to the number of students working at it?

c) Are hexagonal benches suitable for teacher demonstration? Where does the teacher stand? Can the demonstration be seen?

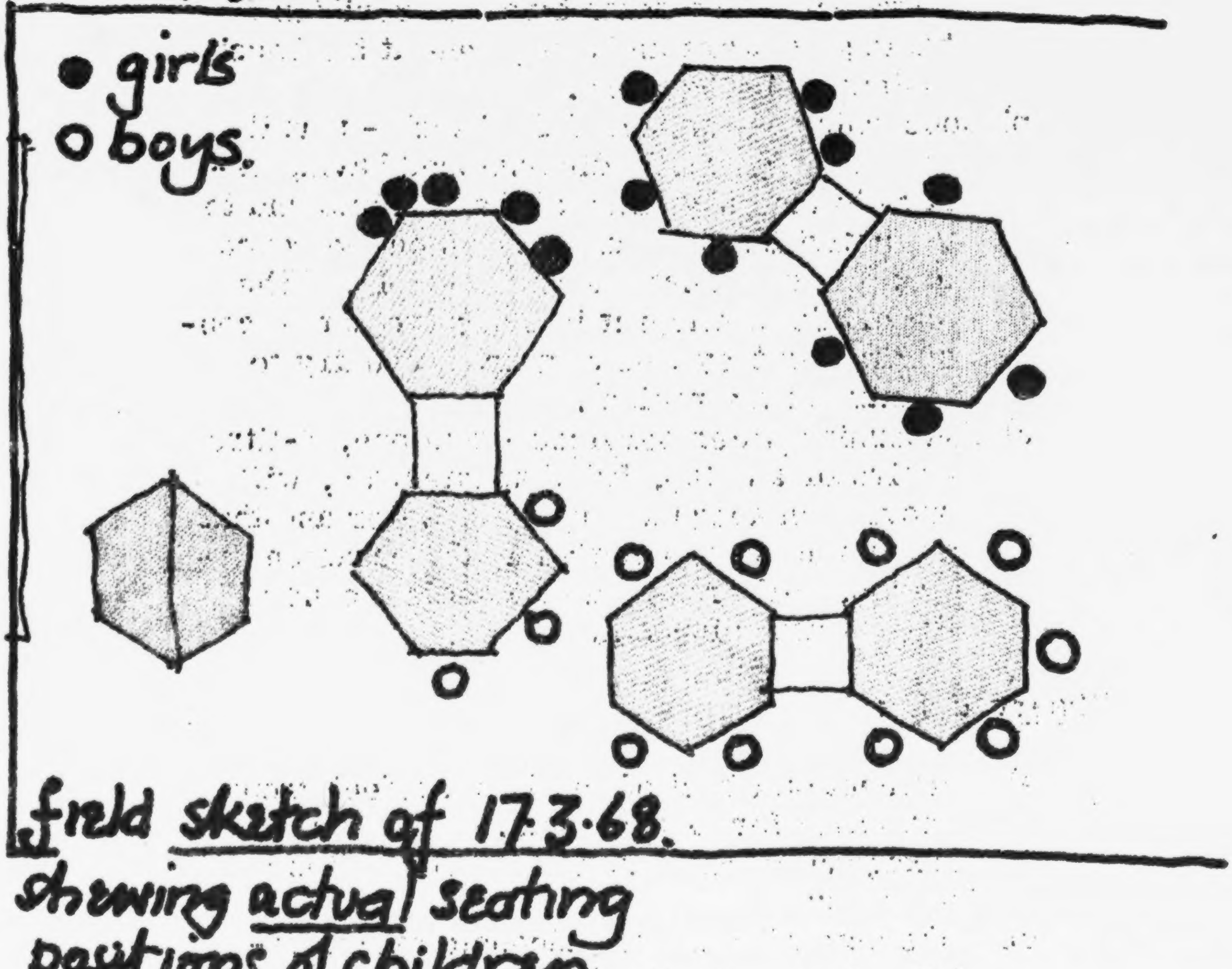
d) Is the glassware provided at the bench adequate? Can it be conveniently reached?

e) Record the date and the time each aspirator is refilled on the attached form. Is the use of an aspirator convenient? Does it get knocked over? Does it drip?

f) What problems, if any, are connected with the use of a "mobile sink"? Are breakages noticeably more or less due to dropping glassware in the sink?

A summary of the various comments is given below in relation to the heads of observations:

a) The effect of bench shapes on student group fortion The school is co-educational. The boys and girls sit (of their own volition) at separate benches. 11/ This leads to over-crowding at some benches and under-utilization at others (Figure 5).



field sketch of 17.3.68.
showing actual seating positions of children.

Figure 5 - Actual Seating Positions Adopted by Children at the Benches.

The pattern of seating shown is of very great interest. The boys are seated, as was intended, one on each side of the hexagon, facing the experiment which is in the middle of the bench at somewhat less than an "arm's distance" from each student. Some of the girls on the other hand, have grouped themselves very closely together, two on one side of the bench and three on one corner of a bench. The group of three were so closely seated that, on one occasion they knocked over a bottle of diluted acid and were splashed.

There are at least three solutions to this problem:-

i) To re-shape the bench as shown in Figure 6 so that the girls can sit, as they apparently wish, in pairs. If this solution is adopted it will (as has been explained above) be unsatisfactory in terms of group dynamics and moreover, the formation of four sub-groups per bench will require four times the amount of equipment available.

ii) For the teacher to suggest that it would be more sensible for them each to occupy one side of the hexagon and to point out that in so doing, friends can still sit adjacent to one another.

iii) The bench can be regarded as a wire ring on which are threaded five beads. (Figure 7) The beads can be moved around the ring to the positions required for each teaching or each group situation. The result of this would of course be a circular or oval, rather than an hexagonal bench.

It is clear that the use of the benches requires a full understanding of group psychology on the part of the teacher and to achieve this it may be that some stress should be placed on the need at Training College and In-Service courses to teach the "new" chemistry at the new benches.

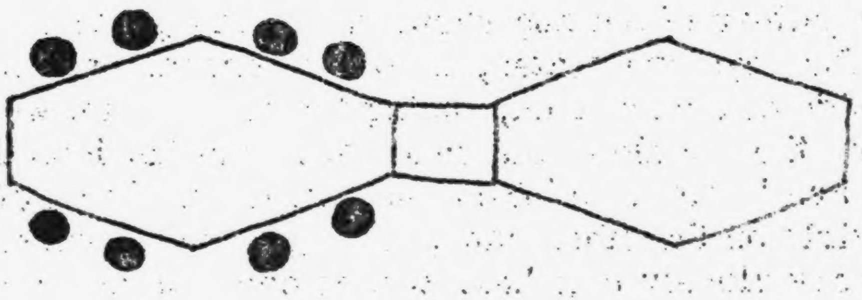
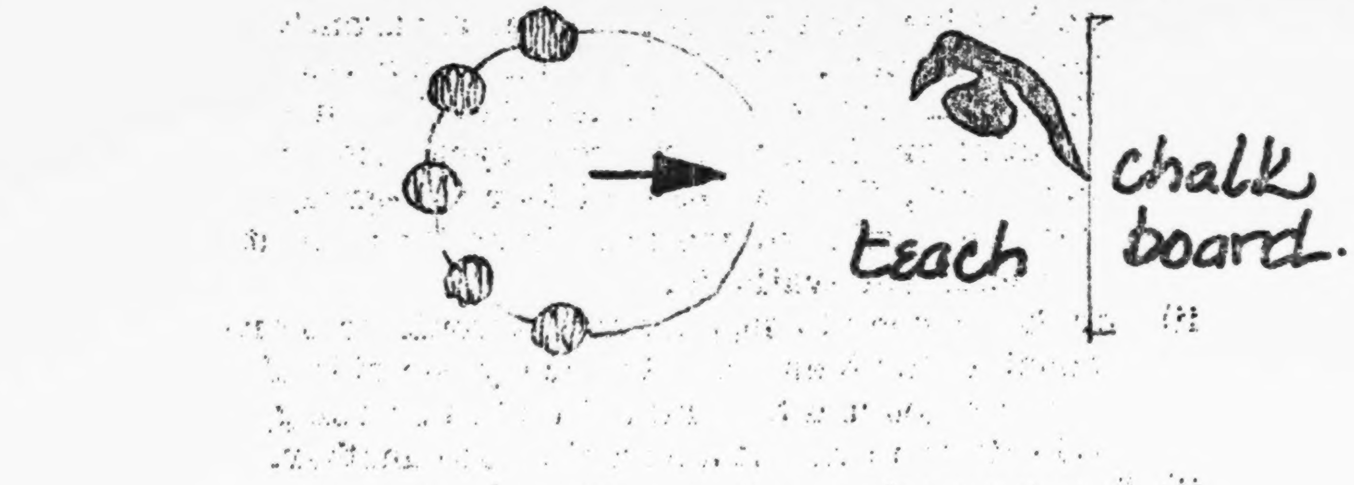


Figure 6 - Possible re-arrangement of Bench to Group Girls in Pairs


chalk board.
teach
Expt.
chalk board.
teach

beads on wire ring analogy
children more as focus of interest moves.

Figure 7 - Circular bench - Beads on Wire Ring Analogy

b) Is the size of the bench adequate having regard to the number of students working at it?

Children in Ceylon carry their books from class to class. Often a student will have as many as ten books, only one of which is actually required for the chemistry lesson. At the start of the trial each student put all of his or her books on the bench causing serious overcrowding. This problem, which is by no means confined to chemistry teaching, was resolved by the provision in the laboratory of a students' book and bag storage unit (Figure 8), a unit which the Institute recommends be placed in all laboratories (see ARISBR Studies 1, 2, 3 & 4). The immediate effect was to ease congestion at the benches and leave adequate and sensible space for experimental work.

Quite apart from the question of space for books the bench was found to provide ample space for experimental work as is clearly shewn in Plate 1 at the front of this paper.

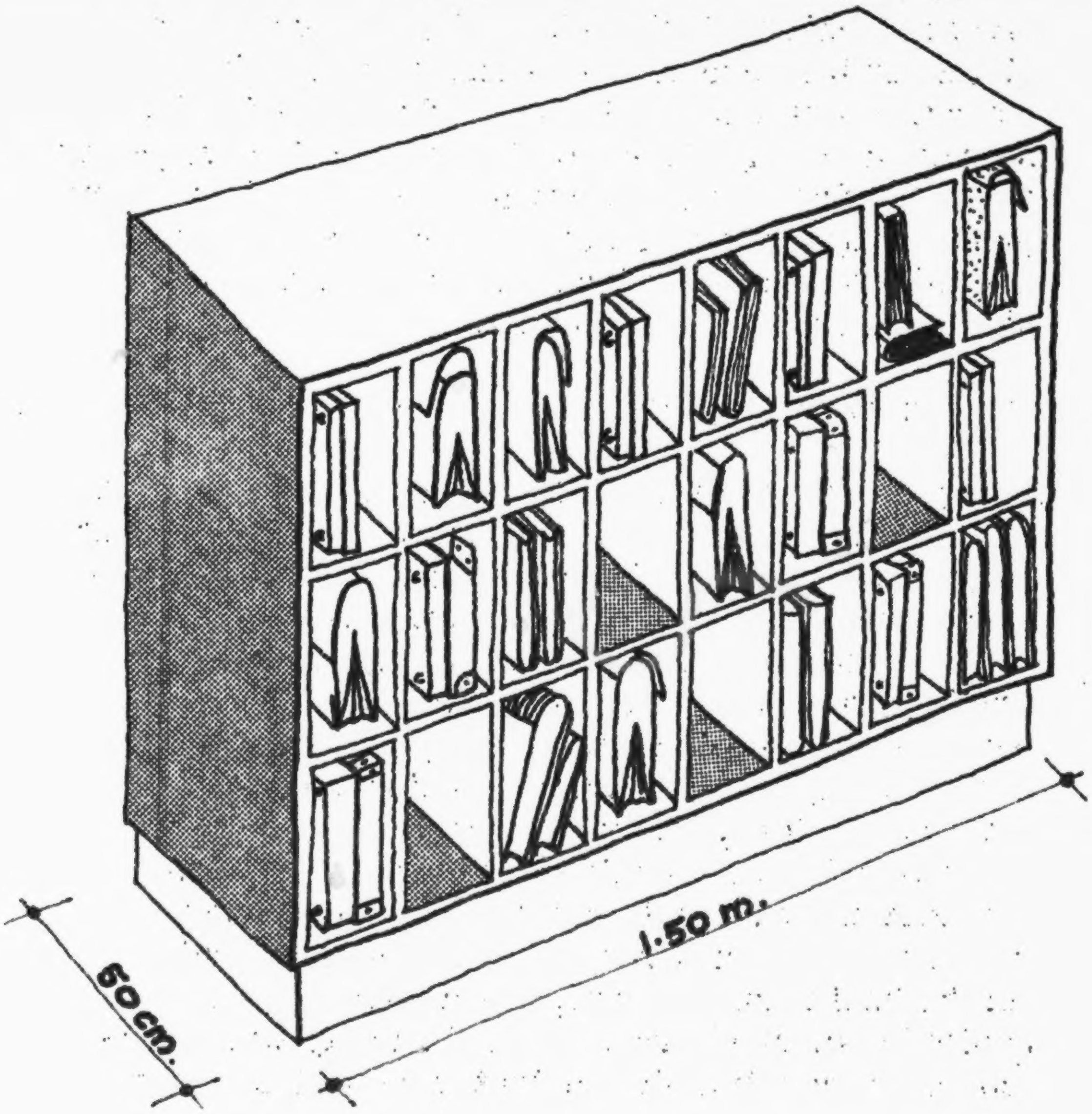


Figure 8 - Students Book and Bag Storage Unit

c) Is the glassware provided at the bench adequate and can it be conveniently reached?

The first prototype benches were provided with a large shelf under the sink on which to store glassware, test tube holders and the like. This could not be reached easily - indeed it reproduced the condition so commonly associated with traditional laboratory benches - that of deep, unaccessible cupboards. As a consequence of this, several alterations to the storage facility were tried, the last of which (Plate 3) was found satisfactory in use.

The question of which items of glassware should be kept at the bench requires further study on the basis of teaching schemes. Frequency of use tables should be drawn up and the items selected on this basis. The provision actually made was minimal and there was a feeling that other items such as pipettes could be included. But the actual use of a pipette is infrequent. Countries adopting the approach outlined in this paper should design the storage unit only after careful study of the frequency of use of glassware and having made the study, leave plenty of space for subsequent changes. It seems unlikely that any two teachers would agree on a single answer to this problem.

d) Is the use of the aspirator convenient?

Although it was clear from the initial study that 3 litre aspirators were needed, in fact only 2 litre plastic aspirators were available. These had to be filled more frequently than planned but only very rarely more than once a lesson. The children seemed rapidly to accustom themselves to the idea that water was in limited supply and, as a result, taps were rarely left with water running to waste.

Plastic aspirators, however, proved to be not the best type for this particular purpose. The tap connection at the bottom was prone to puncture and leak and moreover, when the level of water in the aspirator was low, the aspirator could easily be knocked over. This difficulty was overcome by mounting the aspirator on a block fixed to the bench top. (Plate 3) Clearly heavy 3 litre glass aspirators would be much more satisfactory.

One eminent visitor to the trial suggested that where aspirators were not available, glazed country clay pots could be used in lieu with a rubber tube and pinch clip providing water by syphonic action to the sink. This is an attractive idea to which however, there may be objection, for still water in open pots provides a breeding facility for mosquitoes and for growth of slime.

e) Are there any problems connected with the use of a mobile sink?

In the original prototype where the sink had to be moved upwards it was found difficult to lift easily. A modification was then made to enable the sink to be slid out horizontally and this arrangement has been found quite convenient. (Plate 4)

No drainage is, of course, required with the sink and this, coupled with the absence of water pipes, enables the benches to be moved as desired, a facility which the teacher was glad to use on a number of occasions.

2.7 Other outcomes of the Field Trial

a) The changing attitude of the teacher

The children, in the second year of chemistry study, found little difficulty in adapting themselves to the new arrangements. The teacher had, however, for the past 10 years, been teaching in a traditional laboratory and although enthusiastic in his approach to the new furniture, naturally took a little time to realise its potential.

i) Although the first furniture arrangement to achieve maximum illumination on the benches, was manifestly unsatisfactory from other points of view, it was some time before the very easily moveable bench units were moved into more convenient positions. Later when it was realised that the benches could be moved, their positions were varied from time-to-time until a definitely preferred arrangement was found.

ii) The total teaching programme for the two year course in chemistry involves 75 demonstrations by the teacher and 91 experiments by the students. On 29 occasions there are mixed periods of teacher demonstration and student experiment.

The design of the laboratory must assist the teacher in what is apparently a paradoxical situation. In quite short periods his role may change from that of lecturer to co-worker, from teaching by "chalk and talk" to mentor, merging with and almost becoming one of the students themselves. Although the present teaching schemes require or suggest 75 student demonstrations and 91 student experiments, this represents only the present cycle in curriculum development. Future developments may substantially change this pattern. The laboratory and its furniture must also therefore, be sufficiently permissive in design to accommodate these changes as they are introduced.

It was clear from the field trials that whilst the teacher continues to need a demonstration table and chalkboard, he also needs, when he is working with the students (rather than talking to them) a series of chalkboards located at strategic points around the laboratory. This will encourage him to move about and to teach on the laboratory floor where ever the need arises. (Plate 5)

b) Chalkboard position

At the start of the study when a chalkboard was placed at one end of the room all the "keen" students clustered at the benches close to it. Several boards have the effect of removing this orientation and possibly may encourage those who, by sitting at the "back", appear less "keen".

The simple developments described above form in fact part of a complex teaching problem the fuller implications of which have been well outlined in the Report of the Moscow Conference: 2/

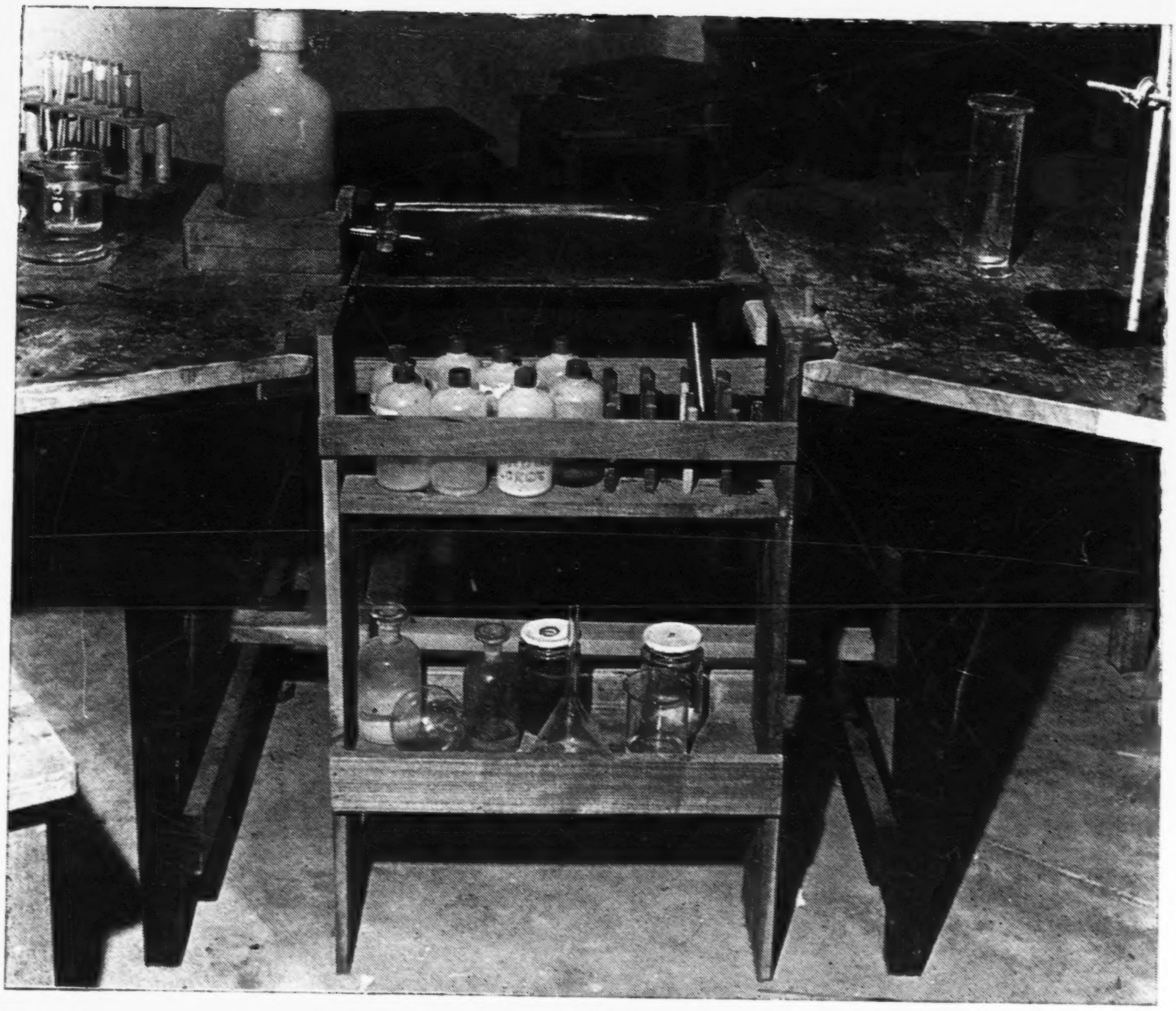


Plate 3. The Detachable Storage Unit

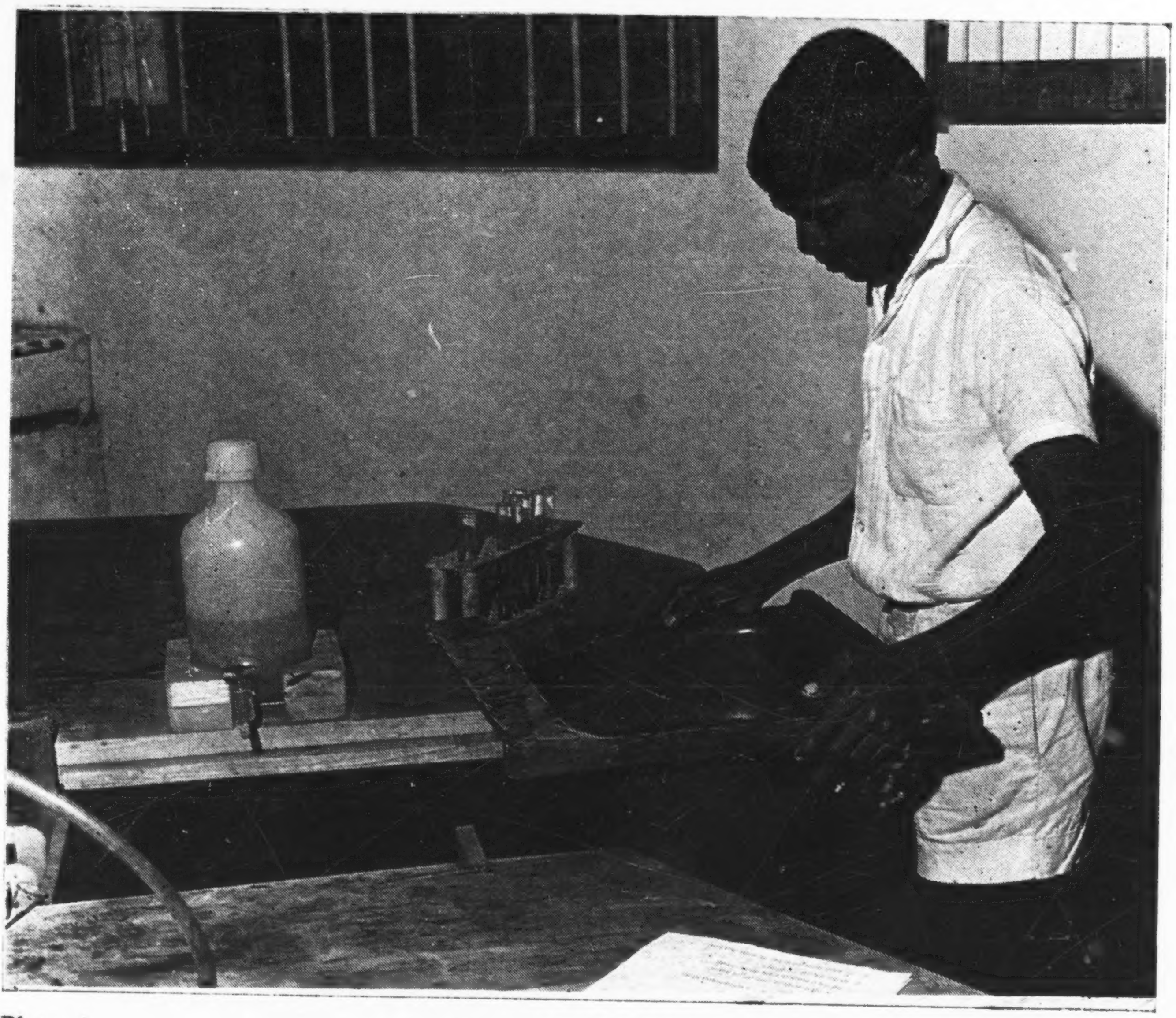


Plate 4. Removable Sink Unit

Plate 5.

Teacher working among the Students

"It is clear that for any particular item that has to be learnt, some resources are more effective than others. So, in any learning sequence, it is reasonable to assume that the efficiency of the process of learning will be a function of the resources brought into play. The issue posed is whether there exists an optimum mix, or whether the same result can be obtained using a variety of mixes."

c) Ancillary benches

It became clear as the Trial continued that there was a need for additional benches for standing experiments as well as for more complicated demonstrations that required preparation in advance of the lesson. Provision for such benches is shown in the drawings of fully furnished laboratories given later in the text.

d) Costs of the new benches

The need to produce economic solutions to the laboratory design problem has already been mentioned. In this context it was thought useful to compare the new benches with those normally supplied in more traditional laboratories. Unit costs, of course, vary from country to country and the simplest comparison is thus of the number of cubic feet of timber required per student place in new and old laboratories. These are given below, the data having been taken from the Institute's collection of working drawings of benches in the Region:

Country A	3.31	cubic feet per place
B	5.34	" " " "
B_2	4.04	" " " "
Commercial Bench C	3.86	" " " "
This study	1.00	" " " "

The reason for the small quantity of timber used in the Field Trial bench is that the study shews there to be no need for either drawers or under bench cupboards. All the equipment needed is stored (and can be easily checked) at the open rack.

Those who are familiar with the traditional bench will also be familiar with the deep, dark inaccessible and therefore, often untidy cupboards under them. The new bench avoids these cupboards and the difficulties associated with them.

General Storage

The total area of shelving required to store the items given in the standard chemistry teaching lists for Ceylon is 24 sq. ft. The measurements were made in the Institute with a complete, current standard set of chemistry material and apparatus. The dimensions obtained are, as is explained below, of transitory importance but the idea of measurement as opposed to guess work in connection with storage is, it is thought, a sound one. The figure obtained is somewhat illusory as the equipment list is based on a first cycle of curriculum development. Another cycle has already been planned and the list is confidently expected to be outdated in the near future. The architect, faced with planning for the unplanned can only keep in very close touch with the curriculum developers and try intelligently to anticipate the requirements emerging from possible future changes.

2.8 Other Laboratory Facilities

Although the main purpose of this study was to develop laboratory benches in relation to the new chemistry, the Field Trial inevitably suggested some of the other needs for a complete facility. The original laboratory was, when the Trial commenced quite empty. Into it were put three pairs of benches, a teacher's demonstration table and some shelving. One blue chalkboard was painted on the wall.

Quite early on in the Field Trial, as has been mentioned above, a need was established for a book and bag storage rack to avoid cluttering the work bench tops with unwanted books. This was provided and proved successful.

Next, the teacher wishing to demonstrate from his demonstration bench, which was a replica of a single laboratory bench, found that the children could not see easily. As a result, a platform was built on his bench and, for a while, he used this successfully. (Figure 9). Later, however, he tended to use one of the group benches for demonstration.

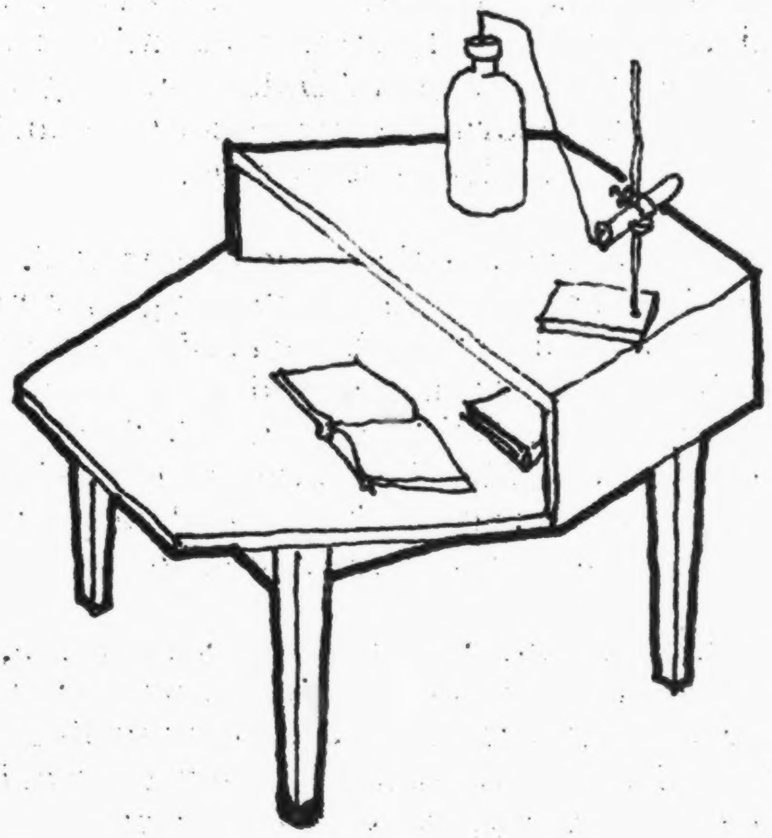


Figure 9 - Platform on Teacher's Bench for Demonstration

The problem with demonstration was, and indeed, continues to be that of re-locating the children so that they can see what is being done. Benches of the type used in the Trial result in some children having their back to the teacher, wherever he demonstrates. This could be resolved by the children moving to a central point for demonstrations or, as is suggested above, by the provision of circular benches around which the children would slide their stools to more favourable viewing positions.

The movement of children has, the Trial shewed, most interesting implications for chalkboard construction and use. In a static, teacher-centric situation the teacher, through the children, soon discovers which part of the board can most easily be seen and which part shines. He adjusts his use of the board accordingly. In the Field Trial, with the benches relocated every few weeks and the children not remaining in well established positions, the use of the board was quite difficult, indicating that in a laboratory for the new chemistry considerably greater attention needs to be given to chalkboard location and finish than might be the case in a conventional laboratory where suitable positions for chalkboards have been long established.

As the Trial continued, further needs emerged. First, the teacher required some space for standing experiments. About 6 sq. ft. of bench appeared to meet his immediate needs. Secondly, whilst it was not desired to keep pipettes at the bench storage unit, their use was felt likely to be of sufficient frequency to justify their storage in the laboratory rather than in the store, and so pipette wall racks were provided, close to the benches to meet this need.

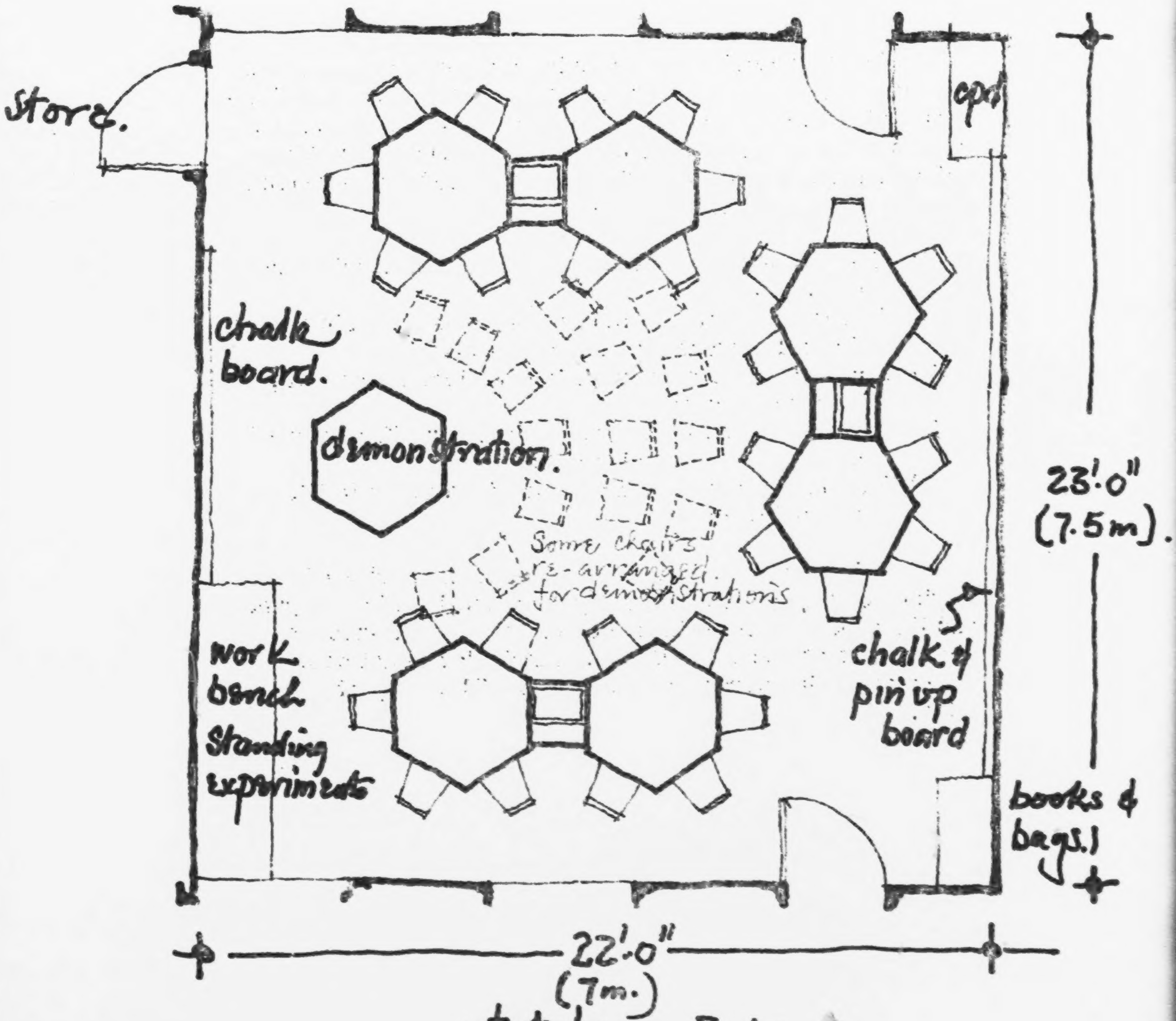
Another point of importance that did not emerge, possibly due to the temporary nature of the Field Trial but which needs consideration, is that of provision for project work by the brighter children. A corner of the room would, in a more permanent laboratory, serve this purpose.

2.9 Laboratory Shape

Most laboratories, for years to come, will probably be rectangular rooms forming part of a chain of similar spaces in longer teaching blocks. The new furniture will comfortably fit into such spaces (Figure 10).

3.0 Future Studies

The emphasis in this paper has been on the changing situation in chemistry teaching in Asia. Several countries are embarking on a second cycle in chemistry curriculum development and, in the years to come, further cycles will occur.


Store.
cpd
chalk board.
demonstration.
Some chairs re-arranged for demonstrations
work bench
Standing experiments
chalk & pin up board
books & bags.
23'.0"
(7.5m).
22'.0"
(7m.)

total area 506 sq.ft
50 m².

area per place 17 □ft
1.7 □m.

Figure 10 - Laboratory in Rectangular Space

If the laboratories are to match the new teaching ideas then the study outlined above must be regarded as completely open ended and in no sense definitive. Indeed even without regard to future development, the Field Trials have themselves caused several questions to be raised which require further study. These include:-

i) What is the best position from which the teacher can demonstrate?
ii) What is the minimum student movement possible such that all students can see demonstrations?
iii) What effects have answers to questions (i) and (ii), on bench design?
iv) What are the optimum group sizes for effective work in chemistry learning situations?
v) What is the optimum grade size in relation to (i), (ii) and (iv)?

What is now needed are studies in the countries of the Region, of the validity of the approach outlined in this paper and the development of laboratories to meet the various situations that occur in different curricular situations. These are being arranged in 1969 and will be reported later.

Working drawings on the benches in both inch/feet and metric scale units are available free on request to ARISBR, P.O. Box 1368, COLOMBO, Ceylon.

References

1. UNESCO. An Asian model of educational development; perspectives for 1965-80. Paris, Unesco, 1966.

2. UNESCO. Meeting of Experts on Curriculum of General Education. Final report. Paris, Unesco, 1968.

3. INDIA. Education Commission, 1964-66. Report; education and national development. Delhi, 1966.

4. COOMBS, P.H. The world educational crisis - a systems analysis. Paris, I.I.E.P./Unesco, 1968.

5. ALLES, JINAPALA. Financing and costs of first and second level education in Ceylon, 1952-1964 [by] Jinapala Alles, S. Victor de Silva [and] Francis W.W. Kulatunga. [Colombo] 1964. Issued by Division of Secondary Education, Ministry of Education, Ceylon.

6. MIDDLETON, M. Group practice in design. London, Architectural Press, 1968.

7. BRUBACHER, J.S. Modern philosophies of education. Tokyo, McGraw Hill, 1962.

8. INDIA. Committee on Plan Projects. Report on science education in secondary schools. Delhi, 1964. (COPP/SS/3/1964).

9. CEYLON. Department of Examinations. Syllabuses of instruction and schemes of work in science subjects for G.C.E. classes: Chemistry. Colombo, 1964-67. 3 vols.

10. ACTA psychologia, 3, 1937: Experimental study of productive collaboration, by M.C. Bos.

11. EDUCATIONAL review, v.19, no.1, Nov. 1966: A study of interaction in small instructional groups, by M.Y. Sawiris.

12. WORLD survey of education, vol.3: Secondary education. Paris, Unesco, 1963.

APPENDIX - I

Part of the unit on Electro-Chemical Corrosion from the Syllabuses of instruction for Chemistry.

Ministry of Education & Cultural Affairs,
CEYLON

Teaching procedures, content and activities	*Main teaching outcomes*	*Notes*
(4-5.20) UNIT TWO Electro - chemical Corrision I Revise quickly (with actual set up apparatus) the conditions for the rusting of iron done earlier, **Unit (4-2.60)**—i.e. air, moisture acidic and salt conditions (and the inhibitive action of alkali conditions). (See **Note 2/1**).	**(2-1)** Air is *necessary* for the rusting of iron. **(2-2)** Moisture is *necessary* for the rusting of iron.	
Make a distinction between the conditions that are *necessary* and the conditions that *assist* or *inhibit*.	**(2-3)** Acidic conditions *assist* the rusting of iron. **(2-4)** Salt conditions *assist* the rusting of iron. **(2-5)** Alkaline conditions *inhibit* the rusting of iron.	**Note 2/1** Some 6 weeks before the lesson (in small bottles) these may be separately tested for, and the results discussed in the lesson. Several other experiments too have to be set up about 6 weeks before teaching.
Before the lesson some field observation of corrosion (fences, bins, barbed-wire, gutter, bicycles etc.) should be made, and these observations used for the lesson. Special attention should be paid to age of the specimens, amount of brown (iron) rust, white (zinc) rust, and the difference in rusting of tinned and zincked iron. Show the small thickness of zinc on galvanized iron by taking a section of GI pipe, polishing to a good shine with emery and viewing under low and medium power of a microscope.		
Discussion : What was noticed with regard to galvanized and ungalvanized iron ?	**(2-6)** The galvanized iron rusts much less than plain iron.	

Teaching, procedures, content and activities	*Main teaching outcomes*	*No'*
And the discarded tins ? **(See Note 2/2).**	**(2-7)** **Tins rust in a short time.**	**Note 2/2** ***Problem :*** (for the better pupils) **How long does a tin take to rust ? Exposure on what side of your house makes for quickest rusting ? What possible explanation may be given ?**
`Bi-mettalic Corrision`		
(1) Experiment : To study the effect of scratching (exposing the iron) on the rusting of tins. (See Notes 2/3, 2/4).		**Note 2/3** This experiment and the next two should be set up by the teacher about *6 weeks* ahead of the lesson. Only the results should be discussed in class. The pupils can set up similar tins after the lesson and watch the progress themselves. This experiment can be accelerated by lightly smearing the scratched and unscratched tins with salt or vinegar solutions.
Obtain 12 new, empty, clean, milk tins. Scratch 1" × 1" of 6 until the iron is exposed, and leave 6 unscratched. Expose all 12 outside a window for about 6 *weeks*.	**(2-8)** The unscratched tins rusted hardly at all.	
What is noticed about the tins.	**(2-9)** Some little rust was seen on the edge that was cut to remove the lid.	
(The slight rusting on the parts that are cut when the lid is removed should be pointed out).		
	(2-10) The scratched tins rusted badly.	**Experiment (1), (2), (3)** may be similarly set up, simultaneously, by the **Teacher.**
Discussion : From the previous knowledge of conditions for rusting (air, moisture, acid conditions salt conditions) what possible explanation may be given for the observation ?	**(2-11)** One possible hypothesis is that the iron, being exposed in the scratched tins, could come into contact with the air and moisture, and hence rust.	**Note 2/4** If tin sheet is available this is better to use because of the similarity of shape to the zinc sheet used in the next experiment. However, tin lids may be cut and used.
Indicate that students are in fact practicing one of methods of the scientist in trying to solve problems—propounding hypotheses and testing them.	**(2-12)** **One possible hypothesis is that the iron, being protected in the unscratched tins could not come into contact with the air and moisture, and hence did not rust.**	

Teaching procedures, content and activities	*Main teaching outcomes*	*Notes*
This hypothesis will have to be tested for validity against further data, and possibly changed if evidence contradicts the hypothesis. Point out that the other coated material met with was galvanized iron. Does the hypothesis just propounded apply here ?	**(2-13)** An appreciation of the methods of the scientist—hypothesis making and testing.	
(2) Experiment : To study the effect of scratching (exposing the iron) on the rusting of galvanized iron. (See Note 2/5).		
Obtain 12, 3″×2″ pieces of galvanized iron sheet (or pipe). Scratch 1″ of 6 pieces of galvanized iron sheet until iron is exposed and leave 6 unscratched. Expose all 12 outside the same window as the tins for about 6 weeks. What is noticed about the pieces ?	**(2-14)** Rust was not seen in the scratched or unscratched galvanized pieces. **(2-15)** Even though the iron was exposed to the air and moisture in the scratched pieces of galvanized iron, rust did not form.	
[*SQMP—What is the difference ? Has the earlier hypothesis to be changed ? Is the zinc/iron rusting differently to the tin/iron*] ? Recall that in the field observations, in galvanized iron articles, white rust (zinc oxide) was seen in some quantity even though brown rust was not seen.		**Note 2/5** **Experiments (1), (2)** may be similarly set up simultaneously by the **Teacher.** (See Note 2/3).
[*SQMP—Does iron in contact with different metals rust differently* ?] **(3) Experiment : To study whether iron, in contact with different metals, rusts differently. (See Note 2/6).**		**Note 2/6.** **Experiments (1), (2), (3)** may be similarly set up, simultaneously, by the **Teacher.** (See Note **2/3**).
Expose for *6 weeks* as in the above **Experiments (1) (2),** polished iron nails wrapped with (*a*) zinc, (*b*) tin, (*c*) magnesium, (*d*) lead, (*e*) copper. Have an unwrapped polished iron nail as a control.	**(1-16)** Iron in contact with zinc and magnesium showed little brown rust.	If the iron nails are galvanized (coated with zinc) the zinc should be removed by dipping in dilute hydrochlorie acid for some time. Wash, dry and then use. The accelerated soda water rusting in the next experiment can be done in a few minutes in class.

Teaching procedures, content and activities	*Main teaching outcomes*	*Notes*
	(2-17) Some white rust was seen on the zinc and magnesium.	
	(2-18) Iron in contact with tin, lead and copper showed much brown rust.	
Where are zinc and magnesium with respect to iron in the Activity Series ? Show a chart of the Series, preferably one with these metals emphasized and another with iron taking a central position.	(2-19) Zinc and magnesium are above iron in the Activity Series.	
Where are lead, copper and tin with respect to iron in the Activity Series ?	(2-20) Lead, copper, and tin are below iron in the Activity Series.	
Discussion : [*SQMP—Does this mean that metals above iron in the Activity Series cause iron to rust less and those below iron in the Activity Series cause iron to rust more ?*] How may this be tested ? Lead to experiments such as wrapping other metals (aluminium, silver), on polished nails and exposing to the air (for 6 weeks). Mention that these are not quick experiments that can be completed in a period. If the rusting can be accelerated, then it may be possible to study the effects in a short time, provided that acceleration does not destroy what is to be investigated.		
Recall again the conditions for rusting and the rusting agents in the atmosphere.	(2-21) Carbon dioxide (carbonic acid) is an active rusting agent in the air.	
Lead to the fact that soda (aerated) water is a concentrated solution of carbon dioxide and may be a fast rusting agent.	(2-22) Soda (aerated) water is a concentrated solution of carbon dioxide.	

APPENDIX - II

Part amended syllabus and part
prototype question paper.

Ceylon General Certificate of
Education (Ordinary Level)
Examination.

2. CHEMISTRY

1. There will be two papers, one of 3/4 hour duration (Chemistry I) consisting of short-answer questions carrying 40% of the marks and a 2 hour written paper (Chemistry II) of the usual type carrying 60% of the marks.

2. Candidates will be required to give evidence, in their answers, of the following:—
   - (i) An understanding of the facts, principles and theories of elementary chemistry as indicated in the syllabus given below.
   - (ii) An appreciation and an understanding of the relevance of elementary chemical facts, principles and theories to everyday life.
   - (iii) A simple appreciation and an understanding of the methods of experimental science as applied in elementary chemistry.
   - (iv) A familiarity with simple apparatus and experimental work. (The possibility of using simple materials, other than standard laboratory apparatus, to perform experiments, should be recognized. Teachers are advised to use such materials wherever they are relevant.)

3. Certain topics are marked with an asterisk. They are to be treated in a simple manner. Simple models, analogies and graphical representation alone to be used where relevant. The questions will test only a preliminary recognition of these concepts.

Content

1. Elementary study of physical and chemical changes; mixtures, compounds and elements, pure substances and their distinguishing features, substances in the home; separof mixtures (as illustrated by examples from everyday life, such as the separation of salt from crude common salt, coconut oil from copra and poonac, sand from rice.)

Change of state, distillation, sublimation.

Solubility, insolublity and miscibility; aqueous and non-aqueous solvents, (as illustrated by common solvents such as kerosine, petrol for insecticides, rubber, grease etc., carbon tetrachloride for grease, oil etc., alcohol for tinctures, perfumes, essences etc., oils for herbal medicines etc.); solubility curves (excluding those indicating a change in the nature of the solute); evidence of solution; saturation, supersaturation (as illustrated by hypo, jaggery); dependence on temperature of the solution, of solids and gases (importance of the solubility of oxygen in water for aquatic life); dependence on pressure, of the solution of gases (as illustrated by aerated water, by nitrogen in the blood in deep sea diving).

Diffusion of gases (excluding quantitative illustration of Graham's Law).

2. The volume composition of air and its significance; air as a physical mixture.

The formal laboratory preparation, collection and properties of oxygen, hydrogen, ammonia, chlorine, sulphur dioxide. (The formal laboratory preparations and collections of carbon dioxide, hydrogen sulphide, sulphur trioxide, nitrogen, oxides of nitrogen, ethane, ethylene are **not** required).

General methods of gas generation and collection in the laboratory.

3. Combustion; conditions for combustion (oxygen concentration, intimate contact between reactants, ignition point); combustion as illustrated by matches, fireworks, explosives etc.; spontaneous combustion; complete and incomplete combustion; the Bunsen flame; flame colours of metals (as illustrated by fireworks etc.); essential requirements for fire extinguishing (removing one or more of the conditions for combustion), soda-acid and foam extinguishers (materials used and construction); safety and strike-anywhere matches (composition and characteristics—not manufacture), inflammable substances in the home; recognition of common textiles by burning (textiles such as cotton, rayon, wool, silk, nylon, dacron, terylene, etc.) .

4. General methods of formation and reduction of oxides; acidic, basic and amphoteric oxides.

Acids, properties of the common acids,-hydrochloric acid, sulphuric acid, nitric acid, carbonic acid, acetic acid (vinegar).

Bases, properties of the common bases, sodium hydroxide, calcium hydroxide ammonium hydroxide.

Salts, neutralization (as illustrated by salt formation, antidotes for acidic and basic poisons, stings and bites); acid/base titration, indicators.

Acidic, basic and neutral substances in the home.

Water; water in crystals; deliquescence, efflorescence; drying agents.

Action of water and of acids on the following metals:— aluminium, copper mercury, iron, lead, magnesium, tin, zinc.

Action of acids on the following salts:

carbonates, sulphates, nitrates, halides, sulphites, sulphides.

The reaction of sulphuric acid in the preparation of other acids from salts on a laboratory scale. (No formal preparation or collection of the gases involved).

Action of heat on the following oxygen-containing substances:

oxides of calcium, iron, lead, magnesium, manganese, copper, mercury, zinc; hydrogen peroxide, chlorates; nitrates; permanganates.

Action of heat on ammonium salts. (No formal preparation and collection of the gases involved); thermal dissociation (as illustrated by ammonium salts, nitrogen peroxide and calcium carbonate).

Activity series and the related chemical properties including the replacement of one element by another, stability, ease of reduction of oxides, and reaction of metals with water and acids.

5. Ionization; acidity and alkalinity due to hydrogen and hydroxyl ions.

*Acids and bases interpreted in terms of the ability to receive or donate hydrogen ions. *Hydrogen ion concentration, pH.

Electrolysis; electrolysis of acidified water; preferential discharge of ions; silver and gold plating; purification of metals (as illustrated by the purification of copper); Faraday's Laws of electrolysis; Daniel Cell.

Ionic reactions; soft and hard water, *simple interpretation of water softening and soil behaviour in terms of receiving and donating ions; amphoteric substances; hydrolysis.

6. *Electro-Chemical series and its relationship to the Activity series.

Simple understanding of the general conditions for the corrosion of iron, aluminium, zinc and copper.

*Corrosion as an electrical process.

Simple understanding of the effect of the following on the corrosion of iron, aluminium, zinc and copper:—oxygen concentration, acidity and alkalinity, stress. Protection of iron, aluminium, zinc and copper from corrosion (films, coats, additives, *anodic and cathodic protection).

Tests for the following ions:—halide, hydroxyl, sulphate, hydrogen, nitrate, sulphite, sulphide, ammonium and iron.

7. Oxidation and reduction as addition or removal of electro-positive or electro-negative components.

*Oxidation and reduction as addition or removal of electrons.

Oxidising properties of concentrated nitric and concentrated sulphuric acid, and comparision with the properties of hydrochloric acid.

Bleaching and stain removal (by bleaching and by solution).

Chlorine as a bleaching agent and water purifier.

Hydrogen peroxide as a bleaching agent (as illustrated by its production by the ultra-violet rays of the sun and action when water-soaked ink-written paper or moistened clothes are exposed to bright sun-shine—no formal preparation).

8. Laws of Chemical Combination (including Gay Lussac's Law, and the Law of Equivalence); Avogadro's Hypothesis (Law).

Dalton's Model of the atom; atomic weight; equivalent weight; molecule; molecular weight; valence; relationship between atomic weight, equivalent weight and valence; vapour density; relationship between vapour density and molecular weight, gram molecular volume.

9. *Planetary model of the atom; electron, proton, neutron; atomic number.

*The Periodic Table (as an arrangement in order of atomic number).

*Deductions from the Planetary Model of the atom with respect to the ease of removing or of adding electrons, reactivity, metallic-non-metallic character, in the first period of the Periodic Table, and in the alkali metal and halogen families.

*Relationship between valence and the number of electrons in the outermost shell and the position in the Periodic Table.

*Bonds formed by sharing and by donating electrons.

10. **Chemicals from the sea as exemplified by the following:**
Composition of sea water.
Extraction of common salt.
Extraction of bromine.
Electrolysis of brine for sodium hydroxide (diaphragm cell) and sodium hypochlorite.
Hydrogen chloride production from chlorine and hydrogen.
Solvay (ammonia-soda) Process for sodium carbonate.

Chemicals from the earth as exemplified by the following:
The " burning " of limestone, lime mortar, the setting of lime mortar.
*The manufacture of glass, the properties of glass, glass working.
*The manufacture of cement, setting of cement (only conditions—no reactions), concrete, reinforced concrete.
The manufacture of sulphuric acid (Contact Process).

Chemicals from the air as exemplified by the following:
*Liquefaction of air.
Catalytic production of ammonia from hydrogen and nitrogen.
Nitrogen Cycle.

In the above only the important steps in outline and the physico-chemical principles are required. In the cases of the chemicals being manufactured in Ceylon, only the processes as used in Ceylon are required.

CHEMISTRY I

1. Which one of the following substances would not be appreciably present in the air in Ceylon? (i) Neon (ii) Carbon dioxide (iii) Hydrogen (iv) Water.

2. Which one of the following does not give off oxygen when heated with a bunsen burner? (i) MnO_2 (ii) MgO (iii) Pb_3O_4 (iv) $NaNO_3$.

3. A sky-rocket firework gave a bright crimson light. A salt of which one of the following substances may have been used to produce this?
(i) Strontium (ii) Potassium (iii) Barium (iv) Sodium

4. In all the cases when metal A stands higher in the activity series than metal B, which one of the following statements is true?

(i) Both metals will displace hydrogen from hydrochloric acid.
(ii) Both metals will displace copper from a solution of copper sulphate.
(iii) B has greater tendency to oxidize than A.
(iv) An oxide of B should reduce more readily than an oxide of A.

5. A substance effective in removing iron (rust) stains on cloth is:

(i) alcohol (ii) kerosine
(iii) sodium chloride solution (iv) oxalic acid solution

6. Chlorine may be prepared in the laboratory by using one set of the following chemicals:

(i) Granulated zinc and concentrated hydrochloric acid.
(ii) Potassium permanganate and concentrated hydrochloric acid.
(iii) Concentrated hydrochloric acid and concentrated sulphuric acid.
(iv) Sodium chloride and concentrated sulphuric acid.

7. In a balanced chemical equation representing a definite chemical reaction, we should expect to find certain factors on one side the same as on the other. Which of the following would not be the same on the two sides?

(i) Total number of molecules on the right.
(ii) Total number of atoms on the right.
(iii) Sum of the atomic weights on the right.
(iv) Sum of the atomic numbers on the right.

8. In collecting jars of a gas for demonstration, downward displacement of air had to be selected. This was because the gas was known to be:

(i) slightly soluble and lighter than air.
(ii) slightly soluble and heavier than air.
(iii) very soluble and heavier than air.
(iv) very soluble and lighter than air.

9. The following volumes of acid were found to neutralize 25 ml, N/10 alkali in three successive titrations: 23·3 ml; 24·2 ml; 23·7 ml.

Select the best procedure for dealing with these results.

(i) All three should be averaged.
(ii) The first and third should be averaged.
(iii) The second and third should be averaged.
(iv) None of the above.

10. The compound of formula $H_2C = CH_2$ links itself under the conditions of high temperature and pressure to form which one of the following structures?

(i) $-HC = CH.CH = CH.CH = CH.CH = CH-$
(ii) $= C = C = C = C = C = C = C = C =$
(iii) $-H_2C-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-$
(iv) $-C \equiv C-C \equiv C-C \equiv C-C \equiv C-$

11. If sodium sulphide is added to a slightly acidified solution containing the ions — ammonium, cadmium, iron, potassium, sodium, nitrate, chloride — the resulting colour will be:

(i) white (ii) bright yellow (iii) black (iv) bright red.

12. The percentage of dissolved matter in sea water is about:

(i) 0·03% (ii) 0·3% (iii) 3% (iv) 30%.

13. It is impossible to fuse strips of copper, aluminium, iron into soda glass because of a difference in the properties of the glass and the metal.

The property concerned is:

(i) coefficient of expansion. (ii) melting point.
(iii) ignition point. (iv) heat of fusion.

14. Cadmium rods are used in U_{235} atomic reactors mainly to:

(i) Conduct away heat. (ii) Absorb excess ∝ - particles.
(iii) Absorb excess neutrons. (iv) Slow down neutrons.

15. The single equation which shows the final products of the overall action of cold 50% nitric acid on copper is:

(i) $Cu + 4HNO_3 = Cu(NO_3)_2 + 2NO_2 + 2H_2O$.
(ii) $3Cu + 2HNO_3 = 3CuO + 2NO + H_2O$.
(iii) $3Cu + 8HNO_3 = 3Cu(NO_3)_2 + 2NO + 4H_2O$.
(iv) $Cu + 2HNO_3 = Cu(NO_3)_2 + H_2$.

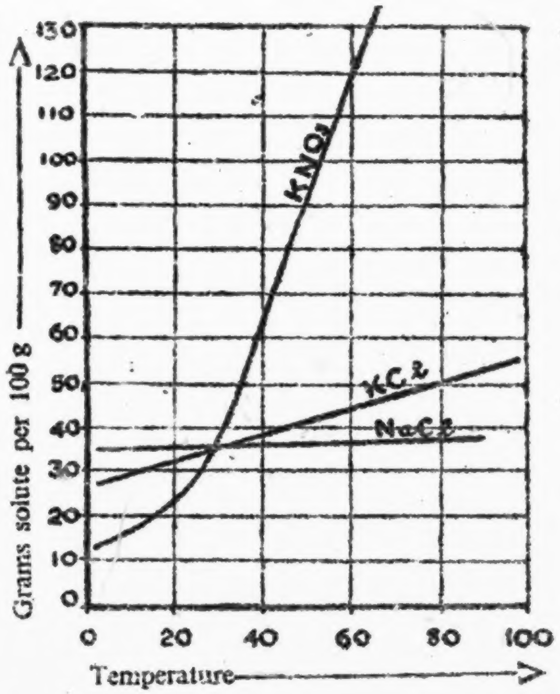
16. Which one of the following solutions, with the pH values given, is most sour?

(i) pH 1

(ii) pH 3

(iii) pH 7

(iv) pH 9.



17. It is possible to obtain a sample of potassium nitrate from a mixture of solutions of potassium chloride and sodium nitrate because:

(i) potassium nitrate is insoluble in a solution containing potassium chloride and sodium nitrate.

(ii) the solubility of potassium nitrate is greater at high temperatures and lower at low temperatures than those of potassium chloride and sodium chloride.

(iii) the reaction $KCl + NaNO_3 = KNO_3 + NaCl$ goes to completion due to the precipitation of potassium nitrate.

(iv) potassium, being more electro-positive than sodium, has a greater affinity for the nitrate ion.

18. When you blow on a candle, it is put out for which one of the following reasons?

(i) The carbon dioxide in the exhaled air is a non-supporter of combustion.

(ii) The moisture in the exhaled air moistened the candle wick.

(iii) The candle-wax vapour was cooled below its ignition point.

(iv) The blowing caused a change in the atmospheric pressure.

Hydrogen was passed over the heated solid products shown in items 19 and 20 below. Which one of the following reactions took place?

(i) $XO + H_2 = X + H_2O$ (ii) $X_2O + H_2 = 2X + H_2O$

(iii) $2X + H_2 = 2XH$ (iv) None of these.

19. Residue after heating magnesium carbonate.	Indicate the number of the appropriate reaction on the answer sheet.
20. Residue after heating copper carbonate.	Indicate the number of the appropriate reaction on the answer sheet.

21. When lead dioxide is converted to lead nitrate, the lead undergoes which of the following changes?

(i) Reduction. (ii) Oxidation.

(iii) Neither oxidation nor reduction (iv) Both oxidation and reduction.

22. When 5 ml hydrochloric acid is added to 10 ml silver nitrate, what will the mixture contain?

(i) Excess hydrochloric acid (ii) Excess silver nitrate

(iii) No excess reagent. (iv) Impossible to say.

23. Compared with another atom of atomic weight 12 and atomic number 6 the atom of atomic weight 13 and atomic number 6:

(i) Contains more neutrons. (ii) Contains more protons.

(iii) Contains more electrons. (iv) Is a different element.

24. It is thought that atoms combine with each other such that the outer most shell acquires a stable configuration of 8 electrons. If stability were attained with 6 electrons rather than with 8, what would be the formula of the stable fluoride ion?

(i) F^- (ii) F^+ (iii) F^{3+} (iv) F_2'

25. The formula of the compound of the same homologous series as $CH_3\,CH_2\,CH_3$, but with 5 carbon atoms is:

(i) $CH_3.\ CH_3.\ CH_3.\ CH_2.\ CH_3.$ (ii) $CH_3.\ CH_2.\ CH_3.\ CH_2.\ CH_3.$

(iii) $CH_3.\ CH.\ CH.\ CH_2.\ CH_3.$ (iv) $CH_3.\ CH_2.\ CH_2.\ CH_2.\ CH_3.$

26. Reaction between neutral barium chloride and sodium carbonate goes to completion because:

(i) A gas is formed. (ii) The reaction is reversible.

(iii) Barium carbonate is insoluble. (iv) Sodium chloride is more stable than sodium carbonate.

27. When brass pins are tin-plated by the use of stannous chloride solution, the element that is reduced is:

(i) Tin (ii) Copper (iii) Zinc (iv) Brass

28. at 200°C.

Pressure (Atmos)	10	100	300	1000
Percentage Conversion	50	82	91	99

To which one of the following reactions could the behaviour shown in the above table not apply?

(i) $CO + 2H_2 = CH_3OH$ (ii) $N_2 + 3H_2 = 2NH_3$

(iii) $N_2 + O_2 = 2NO$ (iv) $3C_2H_2 = C_6H_6$.